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Project Sand Storm—An Experimental Program in Atmospheric Diffusion

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Abstract

A series of field experiments in atmospheric diffusion was conducted at Edwards Air Force Base, California, in 1963. The primary feature which distinguished this series from similar experimental investigations was that instantaneous sources were studied. Puffs of tracer material were generated quasi-instantaneously by short bursts of small, horizontally fired, solid propellant rocket motors. Tracer samples were collected on a horizontal grid that had 350 sampling positions. All of the 43 experiments were conducted under thermally unstable atmospheric conditions.

Analyses of the data identified the region of the turbulent energy spectrum which contains the eddies that are effective in diffusing the clouds. Eulerian measurements of turbulence are shown to be correlated with lateral rates of cloud growth. Downwind distributions of peak inhalation-level dosages were found to be quite irregular, with the anomalies unpredictable on the basis of measurable meteorological parameters. It was, nevertheless, possible to develop an operationally useful estimating equation relating peak dosages to distance from the source.

Contents

PROJECT SAND STORM—AN EXPERIMENTAL PROGRAM IN ATMOSPHERIC DIFFUSION

I. Introduction

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A field test program in atmospheric diffusion was carried out at Edwards Air Force Base, California, over a 9-month period in 1963. For ease of reference the program was nicknamed Project Sand Storm. It was designed primarily to provide operationally useful statements of dilution rates of pollutant clouds from small-volume, quasi-instantaneous sources. Motivation for the program arose from the necessity for using existing test facilities at the Air Force Rocket Propulsion Laboratory to static fire rocket motors whose exhausts contained substantial amounts of toxic materials, and the inability to estimate with any degree of confidence the magnitude of the resulting toxicological hazard.

Although recent studies of a similar nature had yielded the technical information needed to solve related Air Force problems (Barad, 1958; Barad and Fuquay, 1962; Haugen and Fuquay, 1963; Haugen and Taylor, 1963), there were significant differences which made the previous studies inapplicable to the current problem. The basic difference was in the character of the pollutant cloud. The short burst of a rocket motor can be likened to a quasi-instantaneous source that generates a puff. All the previous studies had been concerned with plumes generated by continuously emitting sources. While it is generally accepted that the behavior of

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puffs in the atmosphere differs from that of plumes, the laws governing the diffusion of puffs were not well substantiated. Theoretical investigations of the behavior of puffs, important as they might be for guiding the field studies, were not sufficient for solving the operational problem. Further, the few experimental studies that had been conducted had had very limited objectives and were of little use for determining the diffusion rates of clouds generated by static-fired rocket motors.

A preliminary analysis of the problem at Edwards indicated that a substantial field test program would be required to produce the data needed to solve the immediate operational problem. Even a minimal program for measuring the horizontal distributions of dosages downwind of the motor-firing point called for a densely instrumented sampling grid. Meteorological support requirements included wind and temperature profiles from near the surface to 200 feet and a sufficient number of surface wind measurements to define significant features, if any, in the horizontal flow patterns over the sampling grid. Supplemental information on the initial cloud size and height was considered essential because of the unknown source configurations. The latter requirement was satisfied at least partially by double phototheodolite measurements.

The design and direction of Project Sand Storm were undertaken by the Air Force Cambridge Research Laboratories at the request of the Air Force Rocket Propulsion Laboratory which, in turn, provided funding, logistic support, and technical services. Logistic support included construction of the sampling grid, provision of trucks for service, and facilities for maintaining the equipment. Technical services included the reduction and processing of meteorological and tracer sampling data.

Personnel of the 6th Weather Squadron, 4th Weather Group, Air Weather Service, installed, maintained, and operated the sampling equipment. Personnel of Detachment 21, 4th Weather Group, maintained and operated the meteorological equipment. The Air Force Flight Test Center provided the personnel and equipment for making phototheodolite observations. Coordination of the varied activities of all participating units was provided by AFCRL.

The following is a list of the personnel who participated in the field test program:

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The three objectives of this report are: (1) to describe the program, (2) to present some findings of an operationally oriented analysis, and (3) to present some of the test data. The first objective is accomplished in Chapters II through VI which deal with the design and description of the field experiments and include discussions of tracer-dosage measurements, meteorological measurements, and the procedures used in data reduction and processing. The second objective is met in Chapter VII in which an analysis of the Sand Storm data is directed toward the solution of a specific operational problem. The third objective is completed in the appendices, where one will find tabulations of tracer sampling and source data in Appendix A, phototheodolite data in Appendix B, and intensity of turbulence measurements in Appendix C.

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Barad, M. L., and Fuquay, J. J., eds. (1962) Green Glow Diffusion Studies, AFCRL, Geophysics Research Paper No. 73

Haugen, D. A., and Fuquay, J. J., eds. (1963) The Ocean Breeze and Dry Gulch Diffusion Programs, AFCRL Research Report 63-791(I)

Haugen, D. A., and Taylor, J. H., eds. (1963) The Ocean Breeze and Dry Gulch Diffusion Programs, II, AFCRL Research Report 63-791(II)

II. Diffusion Experiment Design Factors

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and Frederick J. Fowler, Captain**
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The primary objective of the Sand Storm field program was to collect data that could be used to develop operationally useful statements of diffusion rates of puffs released from static-fired rocket motors. The design of the experiments was directed solely toward the accomplishment of this objective, within the framework of constraints imposed by operational limitations and practical considerations. At the outset the following operational limitations were imposed:

a. The sources were to be the short bursts of small rocket motors static-fired in a horizontal position.

b. The tracer material was to be the beryllium contained in the propellant grain and expelled as particulate compounds of beryllium. It is extremely toxic and necessitated elaborate precautions for safeguarding the health of personnel participating in field activities.

c. The source point was preselected.

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**During the period of field test, Captain Fowler was assigned as Staff Meteorologist to AFRPL from Detachment 21, 4th Weather Group. He is currently assigned to the University of Washington.

Based on the first two operational constraints and the requirement for a timely solution, a proven air-sampling technique utilizing readily available sampling equipment was to be used. The assay procedure selected to complement the sampling technique is described in Chapter IV. It has the following significant features which further influenced the design of the experiments:

a. The detection threshold of tracer in the sample was about 0.05 μg Be, but accurate assays were possible only for amounts equal to or greater than 0.5 μg.

b. In practice the range of assessment extended over about 5 orders of magnitude.

c. The assessment procedure was lengthy, costly, and destroyed the sample.

Because of economic and logistic limitations on the number of sampling units that could be supported in the field, and the rate at which sample assessments could be made, a maximum of about 350 samples could be collected per experiment. In addition, the climatology of low-level winds at the site revealed that in order to achieve a reasonable expectance of winds favorable to a test, the angular width of the sampling array had to be at least 90 degrees. Therefore, in order to adequately define lateral and downwind distributions of dosages, the sampling array had to be limited to a horizontal plane. This—together with the uncertainty of the extent of the toxicological hazard associated with the intentional releases of toxic materials, the desire to obtain a statistically significant set of experiments, and the desirability of conducting rocket motor tests during daylight conditions—led to the decision to conduct all experiments under thermally unstable meteorological conditions.

The remaining feature of the basic design was the specification of sampler density in the downwind and lateral directions. Essentially, the problem was that of finding the best compromise, one which permitted an adequate definition of the lateral dosage distribution at as many distances from the source as required to define the downwind distribution of dosages. In making the decision as to the adequacy of lateral, or arcwise, spacing of sampling units, we utilized the statistics of Gaussian distributions. To be wholly adequate, the distribution should be defined by three standard deviations on either side of the mean and have one to two significant samples per standard deviation (Haugen, 1959). This means that the peak should be about 100 times the minimum significant dosage and there should be 7 to 12 samples with significant dosages. With our assay technique yielding a minimum significant dosage of 0.5 μg, the peak would have to be at least 50 μg Be, a factor which also influenced our decision concerning the maximum distance downwind from the source that sampling would be practical.

Arcwise sampler spacing then became a problem of estimating the expected lateral dimensions and growth rates of puffs. Some theoretical (Smith and Hay, 1961; Sutton, 1947) and empirical (Cramer et al, 1958; Aerojet-General Nucleonics, 1962; General Electric Co., 1962) works were used in making these estimates. Our estimates were of necessity crude, but they revealed that we would not be able to include a safety factor in arcwise sampling density if we instrumented a sufficient number of arcs to adequately define downwind distributions. We wished to sample to the maximum downwind distance permitted by source strengths and assay techniques, and at the same time show the effect of source height on close-in surface dosages. It was decided to instrument 10 arcs, giving priority to downwind sampler density at the expense of arcwise density. However, the grid design was made flexible enough to allow changes if during the course of the experiments such changes became necessary. After the fourteenth experiment we concluded that we could eliminate four of the arcs near the source without degradation of the experiments. The sampling units from the discontinued arcs were then allotted to the remaining six arcs, giving a more nearly acceptable arcwise sampling density.

Specifications of the tracer sampling grid are given in Chapter III, Table 2.

Acknowledgments

The authors wish to emphasize that they did not design the experiments alone. Among those who provided valuable guidance and assistance are: Dr. Morton L. Barad, Dr. Duane A. Haugen, and Captain Juri V. Nou of Air Force Cambridge Research Laboratories, and Mr. James J. Fuquay and Mr. Max F. Scoggins of the General Electric Company.

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III. Description of the Diffusion Experiments

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1. INTRODUCTION

From March through November 1963, 43 diffusion experiments were conducted at Edwards Air Force Base, California. All experiments were conducted under thermally unstable atmospheric conditions with westerly or southwesterly winds of sufficient strength (over 5 knots) to assure that the tracer material was carried downwind within the confines of the sampling grid.

2. THE SOURCE

Small, solid propellant rocket motors were static-fired in short bursts to produce the tracer clouds. The horizontally fired motors were aligned approximately with the wind so that the exhaust was expelled in a downwind direction and remained close to the ground for a distance of 75 to 150 feet before blossoming into a puff. However, since the puff had initial finite dimensions, the effective source point for an equivalent point source lay somewhere upwind. Crude estimates, based on ob-

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served initial puff dimensions and growth rates over the shorter travel distances, indicated that the effective source point was very close to the actual firing point.

The relatively large amounts of thermal energy liberated during firings caused the puffs to rise immediately after they were formed. Although it was not possible to accurately determine the effective source heights (because phototheodolite measurements proved to be inadequate for that purpose in most cases), they appeared to vary considerably, depending on the amount of propellant expended and on the wind speed. Based on a limited amount of phototheodolite data and on visual observations, the effective source heights were estimated to vary from a few feet, perhaps 10 to 20 feet, when small motors were fired in strong winds, to 100 feet or slightly more when large motors were fired under light wind conditions.

Firing durations ranged from about 2 to 8 seconds. Propellant grains varied in weight from about 8 to 70 pounds and produced clouds whose visible dimensions were initially 50 to 150 feet in diameter. Source data are tabulated in Appendix A.

3. THE TRACER

Finely divided metallic beryllium, an ingredient of the rocket motor propellant grains, was used as the tracer material. When the motors were fired, compounds of beryllium were expelled and distributed throughout the exhaust cloud. The motors were weighed before and after firing to determine the amount of propellant expended. This, with a precise measure of the percentage by weight of beryllium in the grain, provided an accurate measure of the source strength.

4. TRACER SAMPLING

Sampling techniques and sampling equipment were similar to those used in the Green Glow, Ocean Breeze, and Dry Gulch diffusion programs. In fact, the basic sampling units used in Project Sand Storm were those which had been used previously at Vandenberg AFB and Cape Kennedy in supporting Projects Ocean Breeze and Dry Gulch. The only significant change to the units was the addition of a remote-control shutdown capability, a capability necessitated by the toxic nature of the tracer.

The tracer material was collected on molecular membrane filters mounted 4.5 feet above the ground. Air, drawn through the filter, was metered at a constant flow rate of 3.94 cubic feet per minute by means of a critical flow orifice mounted in the filter head assembly. Aspiration was provided by a Gast, Model 2565V, heavy-duty, vane-type vacuum pump driven by a Clinton, Series 290, Model TBA, air-cooled, four-cycle, one-cylinder gasoline engine (Scoggins, 1962).* One engine-pump assembly was required to aspirate each filter. Figures 1 and 2 show sampling units with typical exposures.

Since the particle-size distribution of the tracer was not accurately known, it was necessary to test the efficiency of the membrane filters to be sure that tracer particles were not lost through the filter. The Gelman Type AM-1 filters, which were used throughout the series of experiments, are rated virtually 100 percent effective in retention of airborne particles of 1 micron diameter and greater.

Figure 1. A Member of the Field Crew, Wearing Protective Clothing and Respirator, is Manually Starting One of the Sampling Units

*Scoggins, M. F. (1962) The field sampling grid. Chap. VI in Geophysic Research Paper No. 73 (I), Bedford, Mass., 1962.

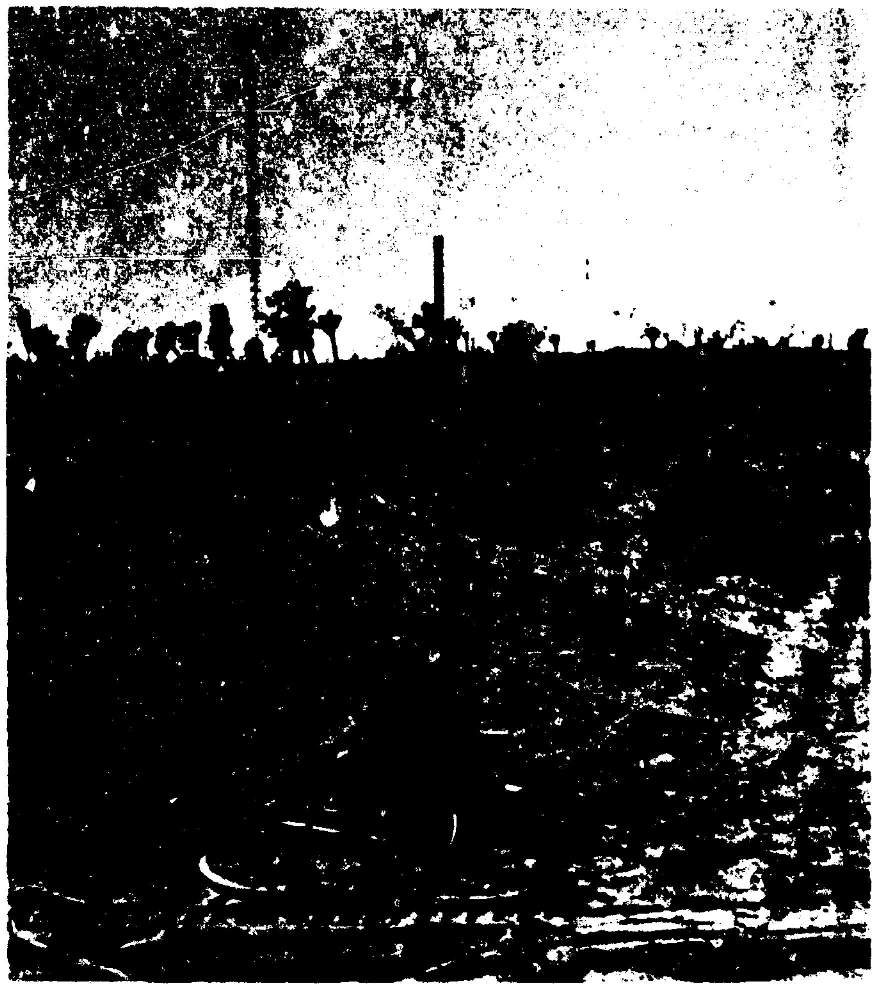

Figure 2. A Sampling Unit With Typical Exposure is Shown. The source point is located near the meteorological profile tower in the background about 300 meters away

These filters were mounted side by side with another type of filter (Millipore Type AA) similarly rated for particles 0.1 micron diameter and greater. Dual samples were collected at 30 sampling positions 200 and 300 meters from the source. Of the 41 pairs of samples so obtained with tracer amounts equal to or greater than 0.5 microgram, no statistically significant difference could be found in the exposures (mass collected normalized for sampling rate) for the 2 types of filter. It was therefore assumed that the particle-size distribution was centered well above 1.0 micron and that the Gelman AM-1 filter was adequate for the experiments.

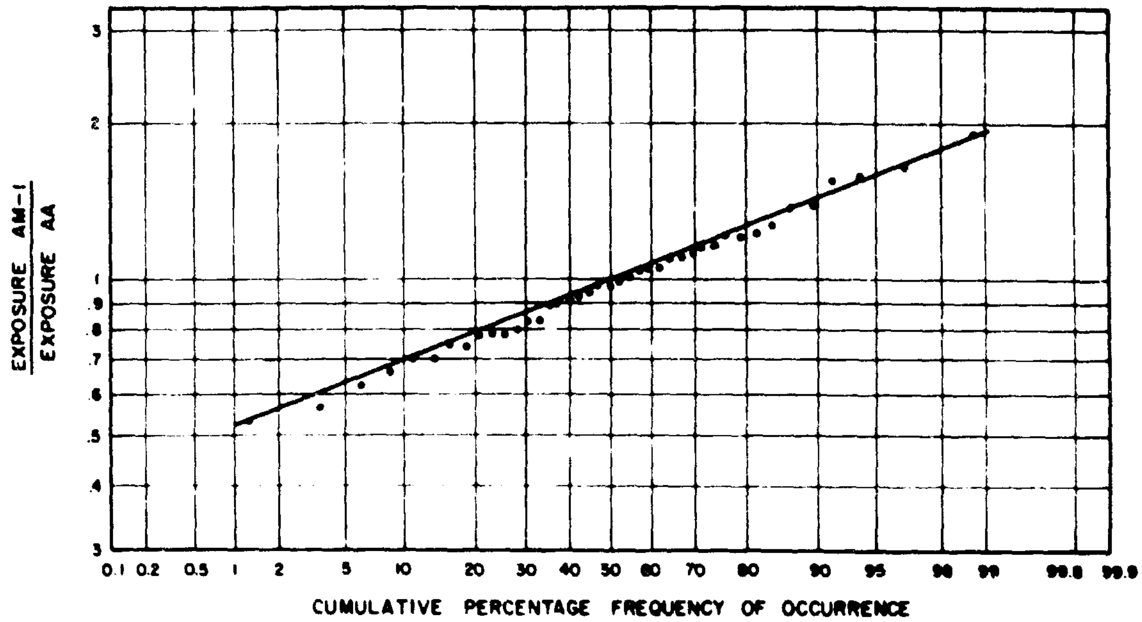

Figure 3. Distribution of the Ratios of Exposures Obtained From Two Types of Filters Mounted Side by Side

Figure 3 shows the frequency distribution of the ratios of exposures obtained from the Gelman AM-1 filter to those obtained from the Millipore AA filter. The mean of the logarithms of the ratios is -0.0117, corresponding to a ratio of 0.973. The standard deviation of the logarithms is 0.1202, corresponding to a factor of 1.32. For comparative purposes, the straight line shown in Figure 3 represents a log-normal distribution with a mean of zero and standard deviation of 0.1202.

In addition to providing information concerning the statistical significance of the departure of the mean ratio from the assumed mean of 1.0, the distribution provides some insight into the reliability of the tracer techniques as applied in the Sand Storm field test program. Since the dual samples were obtained from independent sampling units (a separate engine, vacuum pump, vacuum gauge, and critical-flow orifice were used to aspirate each filter), and the amount of material on each filter was determined independently for each sample, the differences between amounts collected on filters mounted side by side is an indication of the combined error introduced by the sampling and assay techniques. There is of course the implicit assumption that the two adjacent filters were exposed to equal amounts of tracer material. The standard deviation of 0.1202 places the 90 percent confidence limits at a factor of 1.58; that is, measured exposures could be expected to be within the range 63 to 158 percent of an assumed true value 90 percent of the time. Obviously, this is an upper limit of accuracy attained during the Sand Storm experiments. Systematic errors in assay techniques, such as a change in assay instrument calibration curves occurring over a period of weeks, could cause measured values to depart from true values by a slightly greater amount.

5. THE SAMPLING GRID

The tracer sampling units were arrayed on circular arcs concentric on the firing point. As explained in the preceding chapter, during the first experiments measurements of the arcwise distributions of tracer material were given a lower priority than measurements of the axial distributions. Samplers were placed along 10 arcs ranging from 100 to 2400 meters from the source. After a preliminary analysis of 14 experiments, we found that: (1) a greater arcwise sampler density was required to adequately define arcwise distributions, and (2) the density of samplers in the downwind direction could be decreased without significantly degrading the quality of the experiments. The grid configuration was then modified to include six arcs with a greater arcwise sampler density, the total number of sampling units remaining approximately the same. Originally the grid was 90 degrees in width, extending from 17 through 107 degrees true azimuth from the firing point. However, during the course of the experiments it became apparent that wind directions were invariably such that the cloud was never carried toward the northern boundary of the grid. The grid width was then reduced to the 72-degree sector, 035 to 107 degrees. Table 1 shows the various sampling grid configurations.

The motors were fired from Pad C of AFRPL's Test Area 1-16, which was situated near the col of a gentle saddle in the terrain. The land sloped gently downward from the firing point in both the upwind and downwind directions, and rose gently in both crosswind directions. The region upwind 8 miles from the firing point and downwind over the entire diffusion grid was rather regular, sandy, desert floor sparsely covered with sage brush and dotted with Joshua trees. See Figures 4 and 5. Figure 6 shows the general location and layout of the sampling grid.

Table 1. Sand Storm Sampling Grid Configurations

Arc No.	Distance From Source (meters)	Experiments No 1-14 (17^o to 107^o)			Experiments No. 16-27 (17^o to 107^o)			Experiments No. 28-44 (35^o to 107^o)		
		Sampler Spacing			Sampler Spacing			Sampler Spacing		
		Degrees	Meters	No. of Samplers	Degrees	Meters	No. of Samplers	Degrees	Meters	No. of Samplers
1	100	4	6.98	23	-	-	0	-	-	0
2	150	4	10.47	23	-	-	0	-	-	0
3	200	4	13.96	23	2	6.98	46	2	6.98	37
4	250	4	17.45	23	-	-	0	-	-	0
5	300	3	15.71	31	-	-	0	-	-	0
6	400	3	20.94	31	2	13.96	46	2	13.96	37
7	600	3	31.42	31	2	20.94	46	2	20.94	37
8	800	3	41.89	31	1.5	20.94	61	1.5	20.94	49
9	1200	2	41.89	46	1.5	31.41	61	1.5	31.41	49
10	2400	1	41.89	91	1	41.89	91	1	41.89	73
			Totals	353			351			282

Figure 4. Photograph of a Portion of the Sampling Grid. Access roads along the first seven sampling arcs are visible. The sandy desert floor on which the grid is located is sparsely covered with clumps of sage brush and dotted with Joshua trees

Figure 5. Haystack Butte Rises to a Height of About 400 Feet Above the Desert Floor. Located about 1-1/2 miles southeast of the firing pad, it is the nearest prominent terrain feature

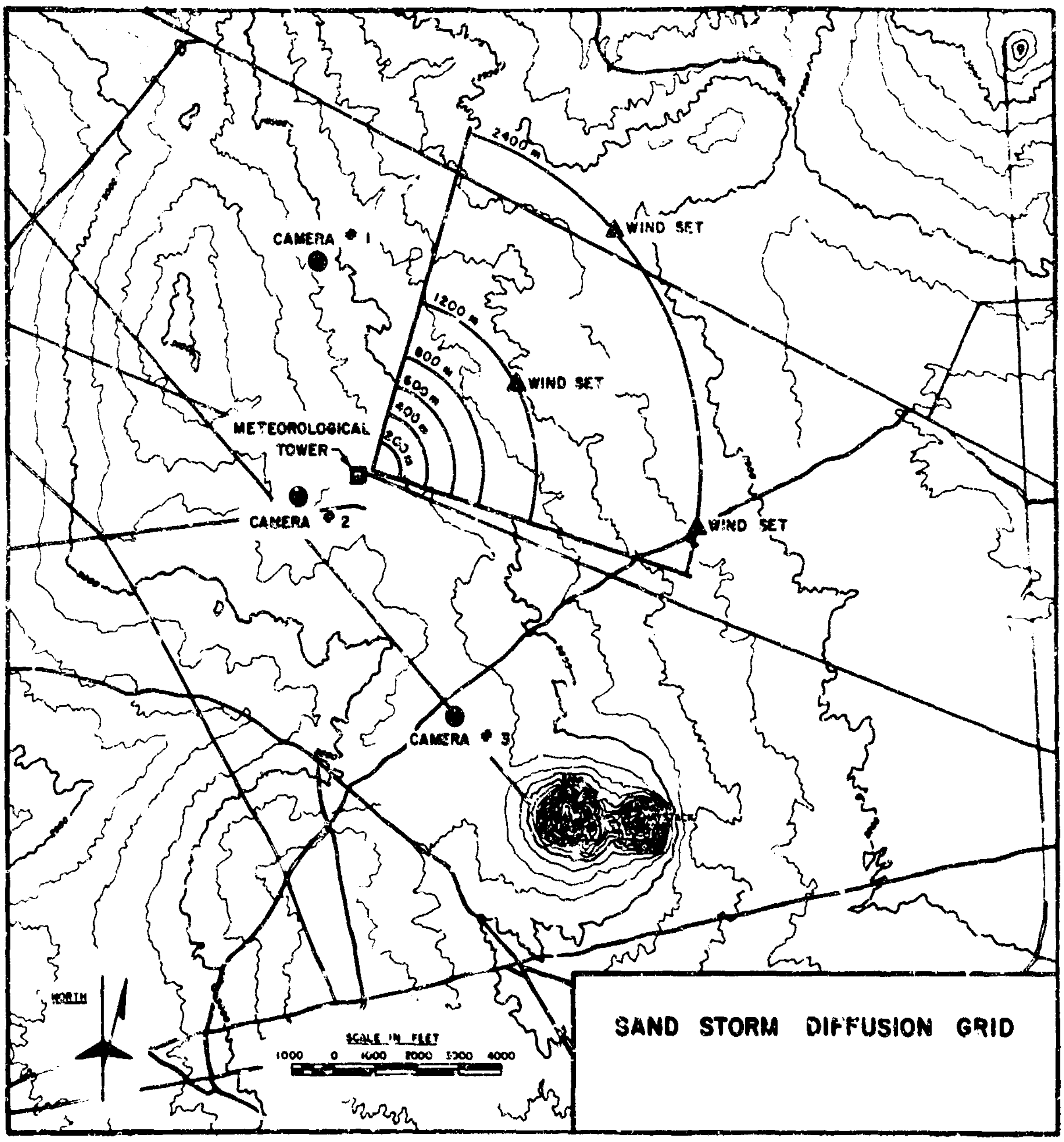

Figure 6. The General Configuration of the Sand Storm Sampling Grid, Meteorological Instrument Locations, and Phototheodolite Camera Positions

IV. Meteorological Instrumentation

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Primary meteorological support was provided by instruments mounted on a 204-foot profile tower located 200 feet upwind from the rocket-motor firing pad. The tower, manufactured by Upright Scaffolds, was an open-frame tubular-aluminum structure, 4 by 6 feet in cross section, assembled from basic units 6 feet high. All wind sensors were mounted on retractable booms extending 12 feet from the tower in a direction perpendicular to the centerline of the tracer sampling grid. The temperature sensors were mounted on 6-foot booms extending in the opposite direction. Wind speed and directions were measured at 12, 50, 100, and 200 feet, wind azimuth and elevation angles at 18 and 150 feet, and temperature differences between 6 and 50, 6 and 100, and 6 and 200 feet. All data were recorded on strip charts.

The requirement that winds be closely monitored prior to firing the motor and during the passage of the cloud through the diffusion course necessitated installing recorders in the central control blockhouse about 1/4 mile from the tower. Unfortunately, there was not sufficient space in the control room to allow installation of all the recorders, so only two were installed in the blockhouse; the remaining seven were installed in a shelter near the foot of the profile tower.

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Through a switching system, signals from any of the four standard wind sets and either of the two bivane sets could be selected for display on the recorders in the blockhouse. In addition, the operation of the chart drive motors for all recorders could be controlled from the blockhouse.

The tower-mounted wind sets were standard Beckman and Whitley instruments (Figure 1). The direction transmitters, Model 1565, were lightweight airfoil vanes attached to a low-torque potentiometer. The wind speed transmitters, Model 1564, were lightweight three-cup anemometers attached to a chopper disc which produced a pulsed signal on a phototransistor. Signals from both transmitters were fed to a multichannel translator, Model 1750, and then to a Texas Instrument Company Rectiwriter dual-channel recorder. The manufacturers' specifications indicate that: (1) over an 80-degree-azimuth range the combined tolerances produced a relative error of less than 1.4 degrees, and (2) above 0.65 knot the wind speed error was less than 1.5 percent or 0.15 knot, which-

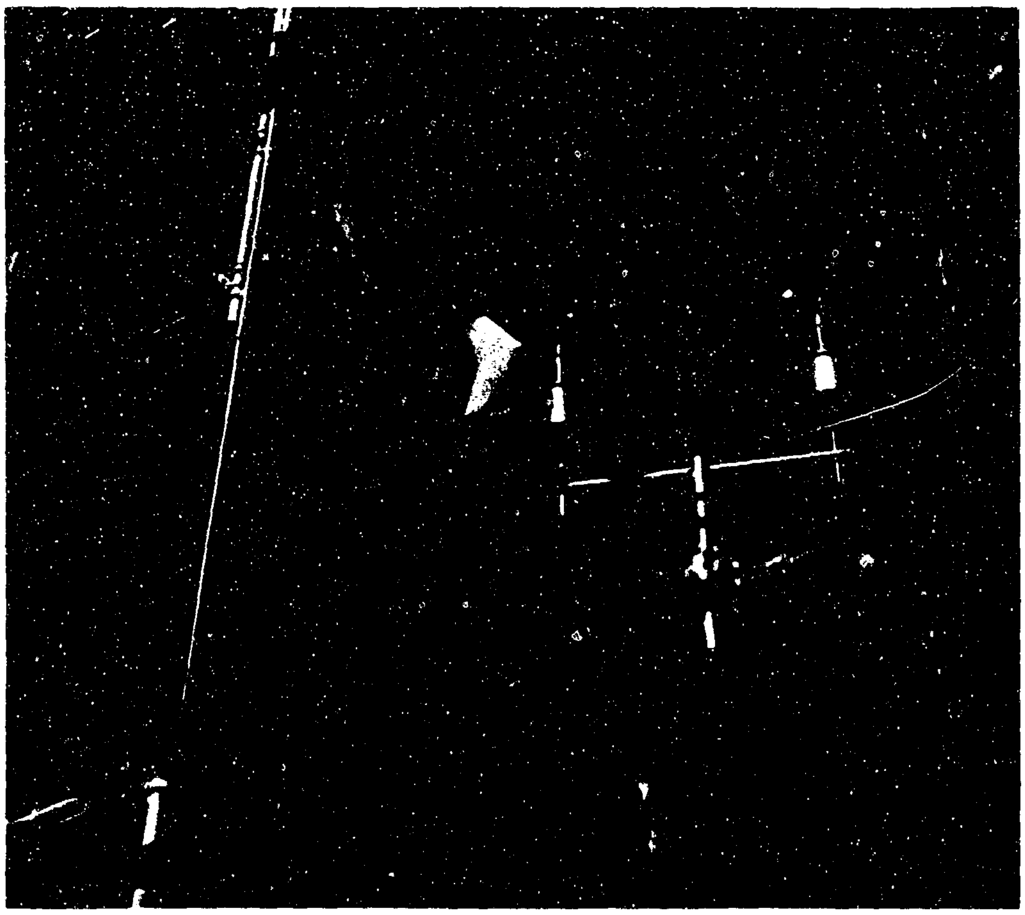

Figure 1. Beckman and Whitley Wind Set Consisting of Lightweight Airfoil Wind Vane and Three-Cup Anemometer

ever was greater. Calibration checks and adjustments for zero and full scale were performed prior to each diffusion experiment.

The bivane equipment was the standard Gelman-Gill rapid response instrument. It consisted of a lightweight bidirectional vane connected to two potentiometers, one for azimuth and one for elevation angle; a power supply translator; and a Texas Instrument Company Rectiwriter dual-channel recorder. A relative error of no more than 1.2 degrees over a range of 80 degrees in both azimuth and elevation was indicated for the system. Unfortunately the bivane sets were not operating until after the tenth experiment, and it was still later in the test series before we were satisfied with the reliability of the data. For these reasons the bivane data are incomplete.

Each of the temperature difference sets consisted of two Leeds and Northrup copper thermohms, Model No. 8195, mounted in Climet Company aspirated temperature shields, Model No. 0.6-1. The thermohms were connected into a self-balancing bridge of a suitably modified Leeds and Northrup Speedomax H recorder. The modification consisted of a variable resistance connected across one arm of the bridge to balance out inequalities in the resistances of the thermohms and interconnecting cable leads. The range of the set was $-10^{\circ}F$ to $+20^{\circ}F$. System accuracy was better than $\pm 0.3^{\circ}F$ over the ambient temperature range of $-50^{\circ}F$ to $+150^{\circ}F$. System response time for 90 percent of a step temperature change was 40 seconds. This slow response was selected to provide a smoothed recording of temperature difference so that mean values over the periods of interest could be interpolated directly from the chart record.

In addition to the meteorological instrumentation on the profile tower, three wind sets were positioned on the diffusion grid. These sets were basically Belfort Type C wind sets which were modified by Control Equipment Corporation to provide greater reliability of operation. The sets are battery powered and record on Esterline-Angus 20-pen operations recorders (see Figure 2). Their use in Project Sand Storm was primarily to determine if there were systematic differences between low-level winds recorded at the profile tower and those observed on the sampling grid. No differences were found.

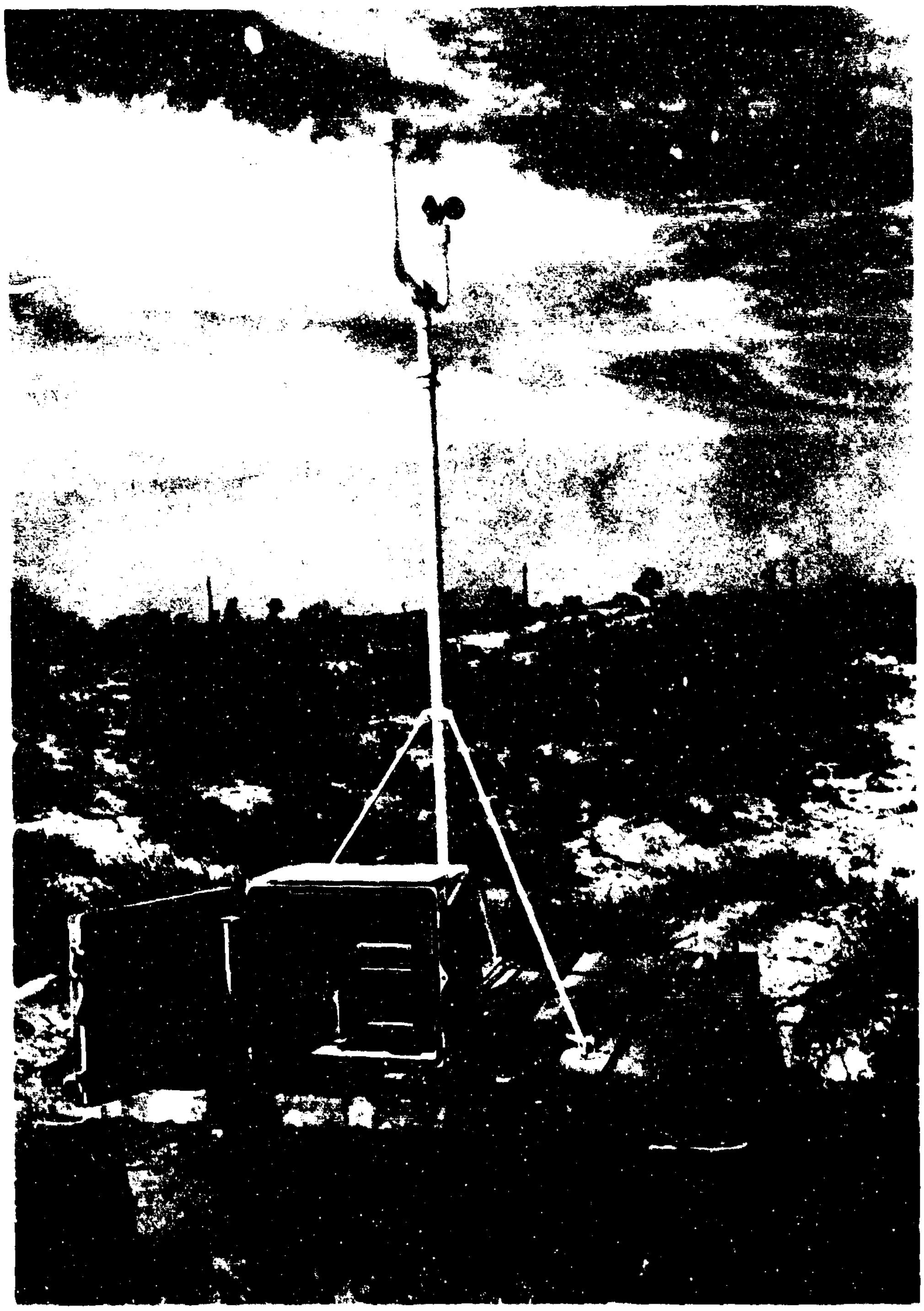

Figure 2. A Modified Belfort Type C Wind Set Consisting of Lightweight Vane and Three-Cup Anemometer and an Esterline-Angus 20-Pin Operations Recorder. The sets are battery powered and were used in remote locations of the test site

V. The Tracer Assessment Technique

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1. GENERAL

Prior to beginning the diffusion experiments, several methods of beryllium assessment (Smythe and Whittem, 1961) were evaluated to determine which was best suited for the routine assay of tracer samples to be collected during the experiments. It was predetermined that the tracer material would be collected on molecular membrane filters that showed no trace of beryllium. It was understood that the samples would be highly contaminated; therefore, the chemical analysis should be specific for beryllium. Operational considerations dictated that the procedure be capable of handling about 400 samples per week on a continuing basis. Additional requirements were:

a. The detection threshold should be no greater than 0.001 μg of Be and the assay procedure adaptable to as much as 500 μg of Be on the sample.

b. The root-mean-square error should be not greater than 5 percent on samples of 1.0 μg or more, and no greater than 10 percent on samples of 0.05 to 1.0 μg Be.

Spectrophotometric and colorimetric techniques were quickly eliminated from further consideration because of their inadequate sensitivity and precision. A neutron activation technique that was tested had the same deficiencies, but not to the same extent; it would have been useful as a scanning device, had there not been technical difficulties that were corrected too late for the technique to be of value in the Sand Storm experiments. Emission spectrographic methods were not considered feasible because they proved to be too time-consuming for the highly contaminated samples.

The morin-fluorometric method (Sill et al, 1961), although a lengthy procedure requiring considerable skill and care, was modified and adapted to provide the required sensitivity and production volume while approaching the stated precision requirements. When tested on samples containing known amounts of beryllium, the modified morin-fluorometric method achieved the precision shown in Table 1.

Table 1. Precision of Morin-Fluorometric Method of Beryllium Determination

Be on Filter	Number of Samples	RMS Error	
(μg)		(μg)	(%)
0.1	23	.0139	13.9
0.5	23	.0224	11.2
1.0	24	.0851	8.5
5.0	21	.3351	6.7
10.0	25	.5852	5.9
20.0	22	1.414	7.1
80.0	21	5.083	6.4

The fluorometric determination of beryllium using morin as a reagent has been reported in great detail elsewhere (Sill et al, 1961). Therefore, only the briefest description is given here, followed by notes on the instrumentation and procedures used for Project Sand Storm assays.

Beryllium reacts with morin (2', 4', 3, 5, 7 pentohydroxy flavone) in an alkaline solution to produce a compound that fluoresces when energized by ultraviolet radiation. Interferences from fluorescent compounds of other metals, such as lithium, scandium, zinc, calcium, and others, are eliminated by addition of a complexing agent (EDTA), making the morin reaction nearly specific for beryllium. A second interference is produced by elements such as copper, silver, and manganese which oxidize morin and destroy the fluorescence. This is eliminated by separating insoluble beryllium hydroxide from the soluble oxidizers before morin is added. Silica is excluded as an interference by precipitation and filtration.

Particular attention was directed to factors affecting the precision of measurements. The temperature of the fluorescing compound was controlled to ± 0.1°C to lessen the effect of changes in temperature on the intensity of fluorescence. A buffer system was employed to stabilize alkalinity which also affects the intensity of fluorescence. Other procedures were adopted so that the assay technique would be consistently reliable and more efficient when applied to a large number of samples. Still other procedures were adopted to allow the technique to be applied by personnel with varying degrees of skill in laboratory methods.

A special laboratory with all the equipment necessary for beryllium assays was set aside in AFRPL's Laboratory Services Division and was staffed with four technicians. After a few weeks the laboratory could handle some 80 to 100 samples daily. Its operations were continuously monitored during the entire course of the diffusion program. Every reasonable precaution was taken to prevent contamination of glassware. Instrument calibrations were frequently checked. Reagent solutions were meticulously prepared with best grade chemicals. In short, every effort was made to insure that laboratory standards were maintained at a peak level.

2. OUTLINE OF THE ASSAY PROCEDURE

This section is devoted to a descriptive outline of the laboratory procedure used for determining the amount of beryllium in Sand Storm tracer samples. Instrumentation, reagents, and laboratory methods differ somewhat from any previously reported work on beryllium determinations, but the procedure closely parallels the morin-fluorometric method reported by Sill et al (1961).

2.1 Instrumentation

A Turner fluorometer Model No. 111 with General Electric mercury lamp No. F4T4/BL was used. The major emission was at 360 mμ. Filters used in the fluorometer were Wratten (2 in. x 2 in.) numbers 2A, 47B, 2A-12, 58, 1-60, and 2 ND. The cuvettes were 12 x 75 mm round pyrex tubes.

2.2 Reagents

Phenol Red. Dilute 0.1 g of the sodium salt of phenolsulphothalein, certified A.C.S. grade, to 250 ml with distilled water.

Morin Solution, 0.008 percent. Dissolve 8 mg of morin (purchasable from L. Light Co., Ltd., Pyle Estate, Colabrook Near Slugh Bucks, England; imported by Leonard Elion, Ph. D., 2 Concord Avenue, Larchmont, New York) in 250 ml of absolute ethyl alcohol. Dilute to 1000 ml with distilled water. Mix. Store in actinic bottle.

Ammonium Chloride Solution, 25 percent. Add 250 g of A.R. grade ammonium chloride to 750 ml of distilled water.

EDTA and TEA Solution. Place 5 g of A.R. grade (ethylene dinitrilo) tetra acetic acid, disodium salt, and 2 g of refined 2, 2' 2" nitrilo triethanol in 100-ml volumetric flask and dilute to volume with distilled water.

Buffer Solution. 156 g of A.R. grade sodium hydroxide, 63 g A.R. grade citric acid, and 37 g A.R. grade boric acid. Make up to 2 liters with distilled water.

Aluminum Nitrate Solution, 0.05 M. Dissolve 37.5 g of $Al(NO_3)_3 \cdot 9H_2O$ A.R. grade in 200 ml of distilled water and make up to 2000 ml.

Beryllium Sulfate Solution, 1 μg Be/ml. Dissolve 0.9820 g $BeSO_4 \cdot 4H_2O$, purified, Fisher Scientific Co., in 10 ml of concentrated sulfuric acid. Heat if necessary. Cool. Transfer solution to 1000-ml volumetric flask containing 200 ml of distilled water. Dilute to volume. Mix. Take 10 ml of this solution and dilute to 500 ml, using 0.1 N sulfuric acid as diluent.

Beryllium Sulfate Solution, 0.1 μg Be/ml. Pipette 10 ml of 1 μg Be/ml into a 100-ml volumetric flask. Dilute to volume with 0.1 N sulfuric acid.

2.3 Procedure

Place filter in 125-ml narrow-neck Erlenmeyer flask. (Use hood.) Wet filter paper with 1 ml of concentrated sulfuric acid. Heat filter until it chars. Cool. Add 10 ml of concentrated nitric acid. Place flask on hot plate that is hot enough to vaporize the sulfuric acid. Heat to dense fumes. Cool. If solution is a yellow to brown color, add 10 ml more of concentrated nitric acid. Add a small amount of potassium perchlorate (0.2 to 0.4 g). Heat until solution becomes colorless and volume of solution is approximately 1 ml. Cool. Dilute solution with 10 ml of water. Filter solution through No. 40 Whatman paper into a 100-ml volumetric flask. Dilute to volume and mix.

Pipette a suitable aliquot (not over 10 ml) into a 15-ml centrifuge tube. Add 1 ml of 25 percent ammonium chloride solution, 1 ml of 0.05 M aluminum nitrate solution, and two drops of phenol red indicator. Mix. Neutralize solution with 1:3 ammonium hydroxide solution to red color. Dilute to 10 ml and mix. Centrifuge at 1200 x gravity for 15 minutes, or sufficient time and speed, to compact beryllium and aluminum hydroxides at bottom of centrifuge tube. Discard filtrate. Add two drops of phenol red solution to the centrifuge tube. Acidify contents of centrifuge tube with 0.05 N sulfuric acid. Add 0.5 N sulfuric acid. Add 0.5 ml of EDTA and TEA solution. Neutralize with buffer solution. Add 2 ml more of buffer solution and mix. Centrifuge at 1200 x gravity for 5 minutes. If a precipitate is present, decant the solution to clean centrifuge tube. Place tube in water bath maintained at 25 ± 0.1°C. When sample temperature is 25°C, add 1 ml of morin solution. Mix and transfer solution to a cuvette and place cuvette in fluorometer. Set the fluorometer slit opening, and place suitable filters in primary and secondary position, as called for in curves No. 1, 2, or 3, to obtain readings on fluorometer previously zeroed against a reagent blank. The reagent blank is prepared the same way as the sample. Obtain the beryllium content from standardization curves.

2.4 Standardization

Three calibration curves are prepared.

Curve No. 1 for 0 to 0.08 μg Be

Place millipore filters in fourteen 100-ml narrow-mouthed Erlenmeyer flasks. With a microburet, transfer volumes of 0.1 μg Be/ml solution to the flasks to give the following concentrations: 0, 0.005, 0.01, 0.02, 0.03, 0.05, and 0.07 μg Be. Treat these standards in the same way as the samples. Set slit at 3 X. Place filters 2A and 47B in the primary position, and filters 58 and 2A-12 in the secondary position. Adjust fluorometer to zero on 0 μg Be sample. Obtain fluorometer readings on each standard. Plot straight-line curve of amount of Be versus fluorometer readings.

Curve No. 2 for 0 to 0.7 μg Be

Place millipore filters in fourteen 100-ml narrow-mouthed Erlenmeyer flasks. Transfer to the flasks, by means of a microburet, volumes of 0.10 μg Be/ml solution to give the following concentrations: 0, 0.05, 0.1, 0.2, 0.3, 0.5, and 0.7 μg Be. Treat these standards in the same way as the samples. Set slit at 1 X. Place filters 2A and 47B in the primary position and filters 2A-12, 58, and 1-60 in the secondary position. Adjust fluorometer to zero on the 0.0 μg Be sample. Obtain fluorometer readings on standards. Set up a straight-line curve based on amount of Be versus fluorometer readings.

Curve No. 3 for 0.7 to 5 μg Be

This curve is prepared in the same manner as curves 1 and 2, except that it is non-linear. The slit is set at 10 X. The primary filters are 2A and 47B, and the secondary filters are 58 and 2ND. The curve is used to obtain an approximate beryllium concentration in samples containing large amounts of beryllium, so that an appropriate dilution factor can be made for subsequent assays using curve 2.

References

Sill, C.W., Willis, C.P., and Flygare, K., Jr. (1961) Improvements in the fluorometric determination of submicrogram quantities of beryllium, Anal. Chem., 33:1671.

Smythe, L.E., and Whittem, R.N. (1961) Analytical chemistry of beryllium. Analyst 86:83-94.

VI. Meteorological Data Reduction and Processing

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Personnel of the Air Force Rocket Propulsion Laboratory reduced and processed the wind data obtained from the Sand Storm profile tower. Wind azimuth-angle measurements made at four tower levels and wind elevation-angle measurements made at two levels were recorded on strip charts at a chart speed of 6 inches per minute for 40-minute periods during each experiment. These analog records were reduced to 1-second digital values using a Benson-Lehner "Oscar J" chart reader that re-recorded the information on punched cards. Each 40-minute record was reduced to digital form but, in general, only the first 10 minutes of each record was processed in the computer routines. Occasionally, however, more than 10 minutes of record was required to adequately define the spectral curve. In these cases the entire 40-minute record was processed.

Two separate computer routines were used to process the digitized wind data. Although one expanded program could have provided the desired information, it was more economical to use two independent programs, each designed to satisfy a specific requirement.

The first and by far the simpler of the two programs, the one whose results were used to estimate the shape of the spectral curve, provided calculations of the amount of energy contained in various regions of the low-frequency end of the one-dimensional turbulent energy spectrum. Elimination of the energy contributed by high-frequency (small) eddies was achieved by averaging data points continuously over overlapping intervals of length s before computing the variance of wind fluctuations. This is equivalent (in electrical terms) to low-pass filtering. The shape and efficiency of this filter and its application in turbulent diffusion analyses are discussed by Smith (1962) and Pasquill (1962).

The input data for the low-pass filter program were the 1-second digitized values of wind data:

$$A_r; \quad r = 1, 2, 3, \cdots, n.$$

For each smoothing interval, s, of the group:

$$s = 2^{m-1}; \quad m = 1, 2, 3, \cdots, 10.$$

A set of averaged data points was found from:

$$(\bar{A}_s)_i = \frac{1}{s} \sum_{j=i}^{s+i-1} A_j; \quad i = 1, 2, 3, \cdots, n_s$$

where the number of averaged data points in the record of length n is:

$$n_s = n - s + 1.$$

The variances are:

$$\sigma^2(\bar{A}_s) = \frac{\sum_{i=1}^{n_s} (\bar{A}_s)_i^2 - \frac{1}{n_s}\left[\sum_{i=1}^{n_s} (\bar{A}_s)_i\right]^2}{n_s - 1} .$$

The second computer program was used to determine the amount of energy contained in various bands of the turbulent energy spectra. The high-frequency energy was eliminated in exactly the same way as in the case of low-pass filtering; that is, the record was smoothed by averaging data points. Low-frequency energy was eliminated by limiting the interval over which the variances were computed. In practice this was accomplished by sampling the smoothed record over overlapping intervals of length T corresponding to a frequency below which energy is to be excluded. The variance was computed for each sampling interval, T, in the period of record, and these variances were averaged. The average was taken as a measure of the energy contributed by periods greater than 2.25 T and less than 2.25 times s (Pasquill, 1962).

As in the previous example, the input data were 1-second samples taken over the period of record:

$$A_r; \quad r = 1, 2, 3, \cdots \quad n.$$

The smoothing intervals were:

$$s = 2^{m-1}; \quad m = 1, 2, 3, 4, 5,$$

and the sampling intervals:

$$T = 2^{m+3}; \quad m = 1, 2, 3, 4, 5, 6.$$

The sets of averaged data points for the various combinations of T and s are:

$$(\bar{A}_{T,s})_{k,i} = \frac{1}{s} \sum_{j=i}^{s+i-1} A_j; \qquad \begin{array}{l} \text{for } k = 1, 2, 3, \cdots, n_T \\ \text{and } i = k, k+1, k+2, \cdots, T-s+k, \end{array}$$

where the number of sampling intervals, T, in the period of record is:

$$n_T = n - T + 1.$$

This process results in $n_r(= T-s+1)$ values of $(\bar{A}_{T,s})$ in an interval of length T. The variances of the $(\bar{A}_{T,s})$ values are:

$$\sigma^2(A_{T,s}) = \frac{\sum_{i=k}^{T-s+k} (A_{T,s})_{k,i} - \frac{1}{n_r}\left[\sum_{i=k}^{T-s+k} (A_{T,s})_{k,i}\right]^2}{n_r - 1}.$$

Averaging the n_T variances over the entire record:

$$\overline{\sigma^2(A_{T,s})} = \frac{1}{n_T}\sum_{k=1}^{n_T}\left\{\frac{\sum_{i=k}^{T-s+k}(\bar{A}_{T,s})_{k,i} - \frac{1}{n_r}\left[\sum_{i=k}^{T-s+k}(\bar{A}_{T,s})_{k,i}\right]^2}{n_r - 1}\right\}.$$

The 29 nontrivial values of $\overline{\sigma^2(A_{T,s})}$ for the combinations of s = 1, 2, 4, 8, 16 and T = 16, 32, 64, 128, 256, 512 represent the intensity of turbulence in various portions of the one-dimensional energy spectrum. These values are shown in Appendix C for azimuth data taken at four levels during each of the Sand Storm experiments. Because of incomplete data and instrument difficulties experienced with the bivanes, similar computations for elevation angles are not included.

References

Pasquill, F. (1962) Atmospheric Diffusion, Van Nostrand Co. Ltd., London.

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VII. An Operations-Oriented Analysis

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1. INTRODUCTION

The objective of this chapter is to present an analysis that was directed toward obtaining an operationally useful solution for the specific problem facing AFRPL test range officials—namely, the ability to estimate the toxicological hazard associated with open-air firings of small, solid propellant rocket motors whose exhaust products are highly toxic. Except for the specific problem at hand, no attempt was made to evaluate theoretical works or to advance the knowledge of diffusion from instantaneous sources; such investigations are left for further analyses where the Sand Storm data may prove useful.

Before beginning the discussion of the analysis, it might be well to define, at least in an intuitive sense, what we mean by diffusion since it can be viewed in several ways. For example, a diffusing puff embedded in an air current is subject to the variations in speed and direction of the current and will be observed to take a meandering, undulating trajectory if viewed from a fixed frame of reference. If viewed from a reference point moving with the cloud, only the growth and dilution of the puff will be observed. When one thinks of diffusion it is ordinarily only the latter process that is considered, and theoretical and experimental work has been limited largely to this concept of diffusion. It is obvious, however, that inhalation-level dosages are to some degree influenced by both the rate of growth of the puff and the height of its center of mass relative to the plane in which dosage observations are made. In the case of a plume, time-averaging virtually eliminates the effect of instantaneous displacements of the plume above or below the time-mean axis. This obviously is not so for a puff. Irregularities in the downwind distribution of dosages are to be expected. However, prior to the Sand Storm experiments it was not known to what extent those influences would be exhibited. If the irregularities caused by variations in the height of the puff above the sampling grid were small compared with tracer dilution rates, an estimating equation could be developed in a form suggested by traditional theoretical work. If they were not, some other approach would have to be taken.

It will be shown in the following discussion that downwind distributions were quite irregular and that the influence of the irregularities was sufficiently strong to severely limit the ability of measurable meteorological parameters to explain the variance of dilution rates observed near the surface. This precluded the development of an operationally useful estimating equation relating downwind dosages to meteorological parameters. In the final analysis, inhalation-level dosages are related by means of probability statements to distances from the source.

2. GENERAL CONSIDERATIONS

The concentration of a pollutant cloud with Gaussian distribution released as an instantaneous point source was shown by Pasquill (1962) to be:

$$\chi(x, y, z, t) = \frac{Q}{(2\pi)^{3/2}\sigma_x\sigma_y\sigma_z} \exp\left[-1/2\left(\frac{x^2}{\sigma_x^2} + \frac{y^2}{\sigma_y^2} + \frac{z^2}{\sigma_z^2}\right)\right]$$

where:

χ = the concentration at time t found at distance x in the direction of travel, at lateral distance y and vertical distance z, relative to the center of the puff,

Q = the amount of pollutant released, and

σ_x, σ_y, and σ_z = the standard deviations of the material about the mean.

If the material is transported with a speed $\bar{u} = \frac{x}{t}$, the dosage, $E = \int_0^\infty \chi \, dt$, can be shown to be:

$$E = \frac{Q}{2\pi \sigma_y \sigma_z \bar{u}} \exp\left[-1/2\left(\frac{y^2}{\sigma_y^2} + \frac{z^2}{\sigma_z^2}\right)\right]$$

and at a given downwind distance the ground-level point passed by the center of the puff receives a dosage:

$$E_p = \frac{Q}{\pi \sigma_y \sigma_z \bar{\bar{u}}} \; . \tag{1}$$

From theoretical considerations of turbulent flow, which incorporate several assumptions that are only approximated in the real atmosphere, Smith and Hay (1961) show that for a puff:

$$\sigma_y \propto \sigma^2(\theta) X$$

and

$$\sigma_z \propto \sigma^2(\phi) X$$

where $\sigma^2(\theta)$ and $\sigma^2(\phi)$ are the variances of the azimuth and inclination angles, respectively, of wind fluctuations and X is the distance from the source.

Equation (1) then becomes:

$$\frac{E_p}{Q} = \frac{k}{\pi \sigma^2(\theta) \sigma^2(\phi) X^2 \bar{u}} \tag{2}$$

where k is a constant of proportionality.

The equation suggests that with a knowledge of the variance of wind direction fluctuations and of the mean wind speed we could predict the peak dosage, normalized for source strength, as a function of downwind distance. One of the first problems that arises is selecting the values for $\sigma^2(\theta)$ and $\sigma^2(\phi)$, inasmuch as it is possible to obtain any number of values of variance from a single wind record simply by changing the range of frequencies over which the variances are computed.

Consider the puff that grows in size under the influence of turbulent diffusion. As the puff grows, larger eddies become more and more effective in distributing the material, while smaller eddies become less important. Therefore, for a given cloud size there exists a range of eddy sizes which is important in diffusing the cloud. Eddies much larger merely move the cloud in an irregular trajectory (horizontal and vertical) as it travels downwind; eddies much smaller ineffectively nibble at the edges of the cloud. However, for an initially small cloud that eventually grows large, all eddies up to those comparable in size to the dimensions of the large cloud play a role in distributing the material. Therefore, it is to be expected that the range of eddy sizes effective in diffusing initially small puffs extends over the high-frequency end of the energy spectrum. The problem is to determine which portion of the turbulent energy spectrum it is that contains the productive eddies. To do so in a deterministic manner is virtually impossible when it is remembered that wind observations taken at a point fixed in space do not adequately define the energy spectrum as observed from a frame of reference traveling with the cloud, the one which is the more relevant in the diffusion of puffs. The shapes of the spectra may be similar, but there is a relative displacement of the spectrum observed from the fixed point toward higher frequencies. The magnitude of this displacement has for some time been a matter of conjecture. Indeed, whether it is a constant or a function of meteorological parameters has not been settled. In this analysis we shall not attempt an investigation of those problems. Rather, we shall content ourselves with determining, empirically, the range of eddy sizes (frequencies) which is effective in diffusing puffs of the size and character under consideration.

By applying various smoothing intervals, s, to serially recorded wind data (that is, averaging the recorded values over time intervals of length s) before computing the variance of wind direction fluctuations, the energy contributed by high-frequency (small) eddies can be eliminated. This is commonly referred to as low-pass filtering. By limiting the period of record over which the variance is taken, the energy contributed by low-frequency (large) eddies can be eliminated. In practice the period of record is not necessarily restricted, but a number of variances are computed, each for a sampling interval of length T. The average of these variances taken over the entire period of record is given as a measure of the energy in the high-frequency end of the spectrum. This is in effect high-pass filtering. Both filters can be applied in computing the variance, thus obtaining the energy within a band of frequencies. The technique used in applying the filters to the Sand Storm wind data is described in Chapter VI.

Assuming that the material within the cloud is distributed normally, the standard deviation of the material observed at inhalation-level is the same as would be observed at any other height. Therefore, for a puff whose center may rise and fall as it is carried downwind, thus causing irregularities in the downwind distribution of ground-level dosages, the most coherent measure of the puff's growth is not the rate of change of magnitude of observed dosages but the change of lateral distributions.

Smith and Hay (1961) hypothesized that the growth rate, $\Delta\sigma_y/\Delta X$, of the initially small puff is approximately constant and proportional to the energy contained in the high-frequency end of the turbulent-energy spectrum. This raises several questions. Is the puff generated by firing a rocket motor "initially small"? What is the appropriate portion of the turbulent-energy spectrum?

For purposes of this investigation, "initially small" means that the initial dimensions of the puff are small when compared with eddies containing significant amounts of energy. By convention (Smith and Hay, 1961) we will define a small puff as one whose initial standard deviation, σy_o, is less than one-tenth the length-scale of turbulence as estimated by the formula (Pasquill, 1962):

$$\ell\,(\theta) = \frac{\bar{u}}{4\pi\, n_{max}}$$

where $\ell\,(\theta)$ = length-scale based on wind-azimuth fluctuations,

$\bar{u}$ = mean wind speed,

and n_{max} = the frequency at which nG(n) is maximum on the curve of nG(n) versus log n. $\sigma^2(\theta) = \int_0^\infty nG(n)\, d\log n.$

Figure 1 shows plots of nG(n) vs. log n for wind-azimuth fluctuations at three heights taken during a 20-minute wind run during Experiment No. 14. Here n_{max} occurs at about 5×10^{-3} cycles per second at all levels. The 12-foot mean-wind speed was 5.3 meters per second, giving a length-scale of 84.8 meters. Examination of σ_y values at 100 meters from the source and phototheodolite data correlated with motor size provided an estimate of σy_o, the initial standard deviation of the cloud. For Experiment No. 14, σy_o was estimated to be 4.6 meters. By definition the cloud is initially small.

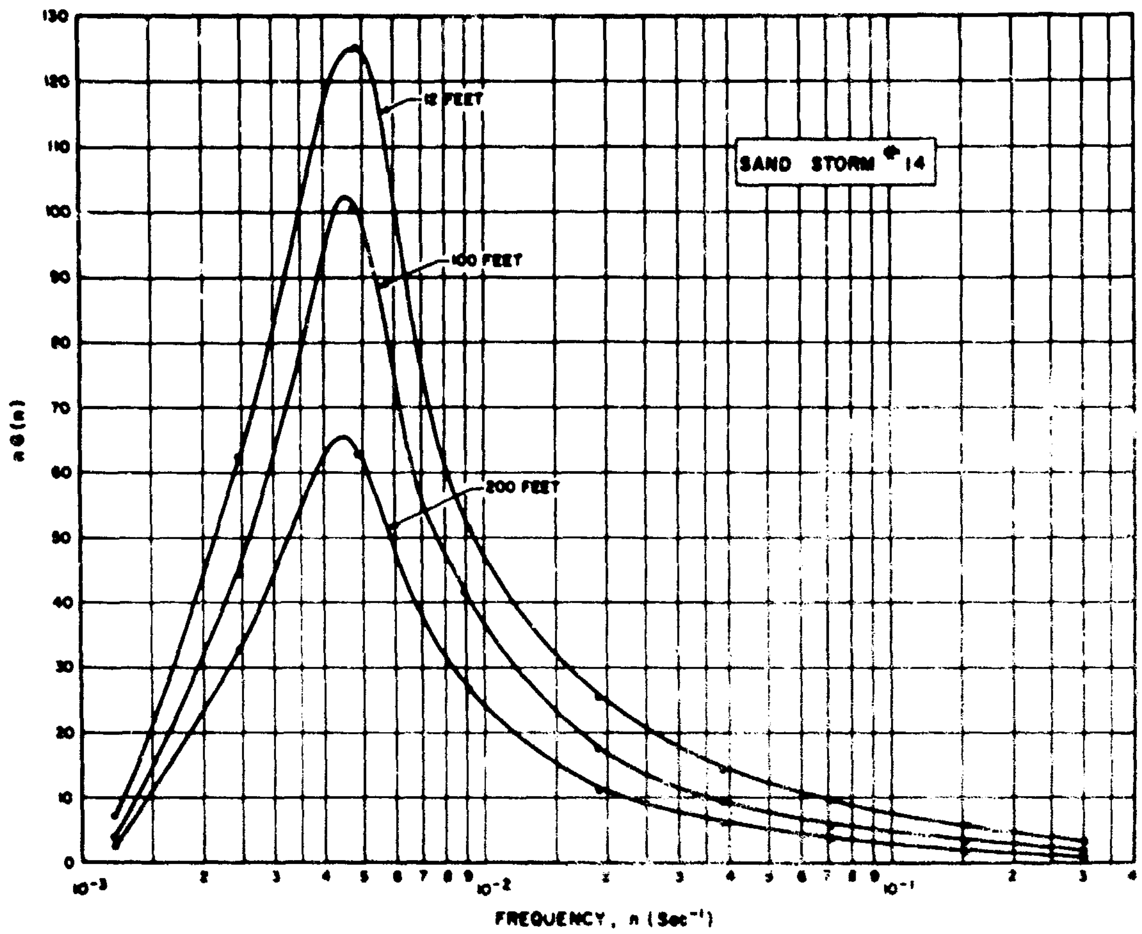

Figure 1. One-Dimensional Turbulent Energy Spectrum Computed for Three Levels of Wind-Azimuth Observations Taken During Experiment No. 14. Computations were based on 20 minutes of data reduced to 1-second readings

The length-scale for each experiment was compared with estimates of σ_{y_0}. It was found that with one exception (Experiment No. 13) the tests produced "initially small" clouds.

To determine which measure of the turbulent energy, $\sigma^2(\theta)_{T,s}$, was best correlated with the rate of growth of the tracer cloud, $\Delta\sigma_y/\Delta X$, correlation coefficients between the two were computed. For each experiment, 87 values of $\sigma^2(\theta)_{T,s}$ (T = 16, 32, 64, 128, 256, 512 seconds and s = 1, 2, 4, 8, 16 seconds) were computed, using the azimuth data recorded by the Beckman-Whitley wind sets. Not all of the measurements of σ_y could be considered valid for various reasons, the chief one being that an insufficient number of samples was exposed to significant amounts of tracer material. A substantial number of measurements were eliminated, even when the criterion for selection was relaxed to the point that: (1) an acceptable distribution be defined by 5 samples having 0.5 microgram or more of the tracer and (2) the peak be at least 10 times as great. After eliminating unreliable measurements, based on these criteria, there were 32 experiments for which $\Delta\sigma_y/\Delta X$ could be computed for the distance interval 200 to 400 meters, 24 experiments for the interval 200 to 1200 meters, 14 experiments for the 200- to 2400-meter interval, and 14 for the 1200- to 2400-meter interval.

The matrices of correlation coefficients obtained by comparing four measurements of $\Delta\sigma_y/\Delta X$ with 87 measurement of $\sigma^2(\theta)_{T,s}$ per experiment are shown in Table 1. There are four observations which immediately suggest themselves. First, the 12-foot wind record provides the best correlations. Second, there is little, if any, advantage gained by smoothing the wind record. This is in accord with the intuitively drawn conclusion that for initially small clouds all eddies in the high-frequency end of the spectrum are effective in the distribution of the material. Third, examining only the 12-foot level, there is a trend for the maximum value of the correlation coefficient to occur at greater sampling intervals, T, as the travel distance (and cloud-size) is extended. This is shown graphically in Figure 2, and is in accord with our intuitive reasoning that larger eddies begin more and more to exert their influence as the cloud grows in size. Fourth, it appears that over the range of travel distances involved there would be but little error introduced if T were selected as 128 seconds and s as 1 second.

One more comment needs to be made about the values of the correlation coefficients in Table 1. Examining only the 12-foot-level correlation coefficients, one notes for $s = 1$ that the highest value for the distance increment 200 to 400 meters is 0.89; for the increment 200 to 1200 meters it is 0.90; for 200 to 2400 meters it is 0.84; and for 1200 to 2400 meters it is 0.87. None of these values is significantly different, statistically, from a true correlation coefficient of, say, 0.87. Therefore, it is probably not valid to conclude that the correlation decreases with increasing distance.

It was not possible to make a comparison of $\Delta\sigma_z/\Delta X$ with measured values of $\sigma^2(\phi)_{T,s}$ since no measurements of the vertical distribution of the tracer were made. However, since all the experiments were conducted under thermally unstable conditions, it is reasonable to suppose that the vertical rate of growth was positively correlated with the lateral rate of growth. It should then be possible to use measured values of $\sigma^2(\theta)$ and $\bar{u}$ to develop an estimating equation similar to Eq. (1) for obtaining expected values of E_p/Q.

Table 1. Correlation Coefficients for $\frac{\Delta\sigma_y}{\Delta X}$ vs. $\sigma^2(\theta)_{T,\,s}$

$\left(\frac{\Delta\sigma_y}{\Delta X}\right)_1$

	12-ft wind						50-ft wind						200-ft wind					
s\T	16	32	64	128	256	512	16	32	64	128	256	512	16	32	64	128	256	512
1	.87	.89	.88	.86	.85	.75	.82	.84	.83	.78	.76	.65	.58	.56	.54	.49	.44	.34
2	.87	.89	.88	.86	.85	.75	.80	.83	.82	.78	.76	.64	.57	.54	.54	.48	.43	.33
4	.87	.89	.88	.85	.85	.75	.78	.82	.82	.77	.76	.63	.55	.53	.53	.48	.42	.32
8	.88	.89	.88	.86	.84	.74	.78	.81	.82	.77	.75	.63	.53	.50	.52	.47	.42	.31
16		.89	.88	.86	.84	.74		.83	.83	.76	.74	.61		.50	.53	.47	.41	.29

$\left(\frac{\Delta\sigma_y}{\Delta X}\right)_2$

	12-ft wind						50-ft wind						200-ft wind					
s\T	16	32	64	128	256	512	16	32	64	128	256	512	16	32	64	128	256	512
1	.88	.89	.90	.89	.88	.79	.83	.86	.86	.83	.81	.71	.55	.52	.51	.45	.40	.30
2	.89	.89	.90	.89	.88	.79	.82	.85	.86	.83	.80	.70	.53	.50	.50	.44	.39	.30
4	.89	.89	.90	.89	.88	.79	.81	.85	.86	.82	.80	.69	.51	.48	.49	.43	.38	.29
8	.89	.89	.90	.89	.88	.79	.81	.85	.86	.82	.80	.69	.48	.55	.48	.42	.37	.27
16		.90	.90	.89	.88	.79		.87	.87	.82	.80	.68		.55	.49	.43	.39	.25

$\left(\frac{\Delta\sigma_y}{\Delta X}\right)_3$

	12-ft wind						50-ft wind						200-ft wind					
s\T	16	32	64	128	256	512	16	32	64	128	256	512	16	32	64	128	256	512
1	.66	.72	.76	.82	.84	.72	.63	.73	.71	.70	.69	.70	.60	.63	.61	.55	.46	.46
2	.66	.72	.76	.82	.84	.72	.64	.73	.71	.70	.69	.70	.60	.62	.61	.54	.46	.46
4	.67	.71	.75	.82	.83	.72	.65	.74	.71	.70	.69	.70	.58	.61	.61	.54	.45	.45
8	.65	.70	.74	.82	.83	.72	.66	.73	.70	.69	.69	.70	.59	.59	.61	.53	.44	.45
16		.66	.72	.82	.83	.72		.70	.67	.66	.69	.70		.63	.65	.53	.44	.44

$\left(\frac{\Delta\sigma_y}{\Delta X}\right)_4$

	12-ft wind						50-ft wind						200-ft wind					
s\T	16	32	64	128	256	512	16	32	64	128	256	512	16	32	64	128	256	512
1	.73	.78	.81	.85	.87	.75	.80	.79	.76	.75	.76	.76	.67	.67	.66	.60	.55	.54
2	.72	.77	.85	.85	.87	.76	.80	.79	.76	.75	.76	.76	.67	.67	.65	.59	.55	.54
4	.72	.76	.85	.85	.86	.76	.82	.79	.76	.74	.76	.76	.69	.66	.65	.58	.54	.53
8	.72	.74	.85	.84	.86	.76	.82	.78	.74	.73	.76	.76	.60	.63	.64	.56	.53	.52
16		.71	.84	.84	.86	.75		.74	.70	.70	.75	.75		.66	.66	.56	.52	.52

$\left(\frac{\Delta\sigma_y}{\Delta X}\right)_1 = \frac{\sigma_{y_{400}} - \sigma_{y_{200}}}{200}$ $\left(\frac{\Delta\sigma_y}{\Delta X}\right)_2 = \frac{\sigma_{y_{1200}} - \sigma_{y_{200}}}{1000}$ $\left(\frac{\Delta\sigma_y}{\Delta X}\right)_3 = \frac{\sigma_{y_{2400}} - \sigma_{y_{200}}}{2200}$ $\left(\frac{\Delta\sigma_y}{\Delta X}\right)_4 = \frac{\sigma_{y_{2400}} - \sigma_{y_{1200}}}{1200}$

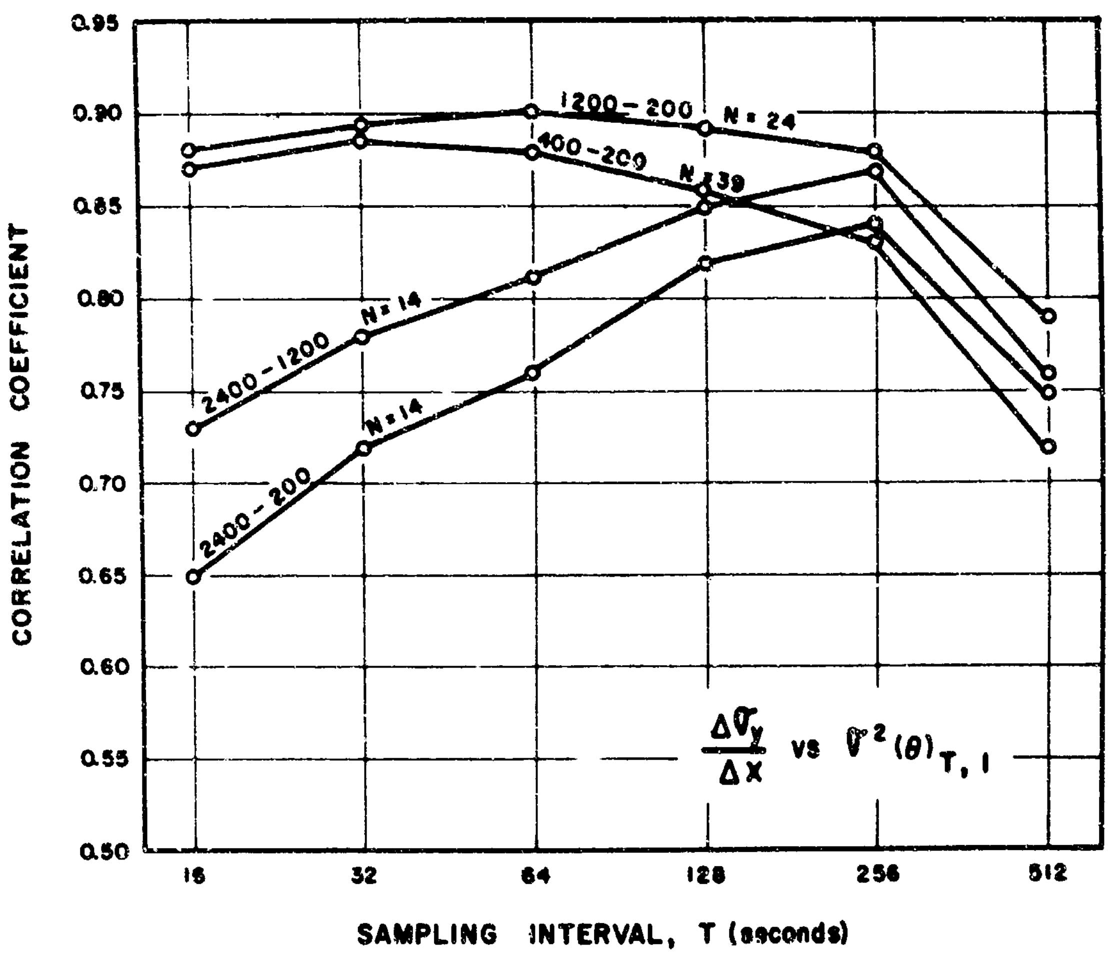

Figure 2. Correlation Coefficients Between Rate of Cloud Growth and the Intensity of Turbulence for Various Travel Distances as a Function of the Sampling Interval. The rates of growth, $\Delta\sigma_y/\Delta X$, are for travel distances 200 to 400 meters, 200 to 1200 meters, 200 to 2400 meters, and 1200 to 2400 meters. N is the number of experiments for which the correlation coefficients could be computed

3. REGRESSION ANALYSIS

A multiple-regression analysis was carried out using an estimating equation of the form:

$$\frac{E_p}{Q} = a\, X^b \left[\sigma^2 (\theta)_{128,\,1}\right]^c \bar{u}^d \tag{3}$$

where $\frac{E_p}{Q}$ = the peak dosage normalized for source strength,

X = distance from the source,

$\sigma^2 (\theta)_{128,\,1}$ = variance of wind direction fluctuations with 1-second smoothing interval and 128-second sampling interval,

$\bar{u}$ = mean wind speed, and

a, b, c, and d are the coefficients of the estimating equation.

This form is suggested by Eq (2) but allows for empirical determination of the estimating equation coefficients, a desirable feature since many simplifying assumptions implicit in Eq (2) are not met in this series of experiments.

The equation is designed to estimate the downwind distribution of E_p/Q in that region which is not influenced to a significant degree by the effective height of the source, that is, in a region that is distant enough from the source so that the inhalation-level dosages resulting from the elevated source are substantially the same as would be observed from a ground-level source. Examination of downwind distributions of E_p for individual experiments indicated that this region on occasion did not include measurements taken within 300 meters of the source. Therefore, the regression analysis was performed on data collected on the five arcs from 400 meters to 2400 meters from the source. Data for the 38 experiments for which we have reliable measurements of E_p at all 5 travel distances are included. The regression analysis yielded:

$$\frac{E_p}{Q} = 2.91\, X^{-1.59} \left[\sigma^2 (\theta)_{128,\,1}\right]^{-.530} \bar{u}^{-.260} \tag{4}$$

where $\frac{E_p}{Q}$ = peak dosage normalized for source strength in units of seconds per cubic meter,

X = downwind distance in meters,

$\sigma^2(\theta)_{128,1}$ = variance of wind-direction fluctuations (with smoothing intervals of 1 second and sampling interval of 128 seconds) in units of degrees squared, and

$\bar{u}$ = mean wind speed in units of meters per second.

The analysis also shows that there is very little reduction of variance contributed by $\bar{u}$. This is not surprising since it was noted that: (1) $\bar{u}$ is not well correlated with E_p/Q, and (2) there is a high correlation between $\bar{u}$ and $\sigma^2(\theta)$. (See Table 2.) Nothing is lost in the way of prediction accuracy when $\bar{u}$ is eliminated from the equation. It then becomes:

$$\frac{E_p}{Q} = 1.25\, X^{-1.59}\left[\sigma^2(\theta)_{128,1}\right]^{-.415} \tag{5}$$

where the variables and units are the same as in Eq (4).

Table 2. Correlation Coefficients Between the Logarithms of Variables in Equations (4), (5), and (6)

	log X	log $\sigma^2(\theta)_{128,1}$	log $\bar{u}$
log $\frac{E_p}{Q}$	-0.67	-0.21	0.14
log $\sigma^2(\theta)_{128,1}$			-0.80

Again, Table 2 shows that $\sigma^2(\theta)$ is not well correlated with E_p/Q. The precision gained by its inclusion in the estimating equation is insignificant. When it is eliminated, the equation becomes:

$$\frac{E_p}{Q} = .180\, X^{-1.59} \tag{6}$$

It can be seen from Table 3, which shows several measures of the accuracy of estimate of Eqs. (4), (5), and (6), that there is really nothing to be gained by the inclusion of the meteorological parameters. The multiple correlation coefficients between logarithms of the observed values of the dependent and independent variables are shown in the second column of Table 3. They are shown here for the reader who is accoustomed to using them as a measure of the precision of an estimating equation. However, the multiple correlation coefficient is not as meaningful a measure as those shown in the remaining columns, because we wish to know the accuracy of estimate of E_p/Q, not the logarithm of E_p/Q. The third column shows the reduction of variance achieved by regression equations containing the various combinations of independent variables. It can be seen that the reduction of variance, while statistically significant, is not high, and that little improvement is realized by

Table 3. Efficiency of Equations (4), (5), and (6)

Independent variables	Multiple correlation coefficient for log $\frac{E_p}{Q}$ and log of independent variables	Percent estimated of variance*	Percent reduction within a factor of 2 of observed $\frac{E_p}{Q}$	Percent reduction within a factor of 4 of observed $\frac{E_p}{Q}$
X	.67	24	45	83
X and $\sigma^2(\theta)_{128,1}$	.70	31	54	82
X, $\sigma^2(\theta)_{128,1}$ and $\bar{u}$	.70	31	53	81

$$\text{* Percent reduction of variance} = 100 \left\{ 1 - \frac{\sum\left[\left(\frac{E_p}{Q}\right) - \left(\frac{E_p}{Q}\right)'\right]^2}{\sum\left[\left(\frac{E_p}{Q}\right) - \left(\overline{\frac{E_p}{Q}}\right)\right]^2} \right\}$$

the introduction of meteorological parameters. Here again, this standard measure of the accuracy of the estimating equation has a serious deficiency when applied to data such as these which extend over several orders of magnitude. It tends to weight too heavily the larger values, in this case E_p/Q values measured close to the source, at the expense of the lower values, or those at the most distant arcs. Another "yardstick" for measuring the accuracy of the prediction equations is the percentage of estimated values which are within a given range of the observed values. In this particular case we have chosen factors of 2 and 4 for two different ranges. The fourth column of Table 3 shows that a slight, but not statistically significant, gain is shown by the inclusion of $\sigma^2(\theta)$, when the percentage within a factor of 2 is used as the measure of prediction accuracy. No improvement in accuracy is shown when the factor of 4 is the measurement criterion.

It is not particularly surprising that the accuracy of the estimating equation is so low, even when tested on dependent data. The reason is that the behavior of a diffusing puff is very erratic, subject to low-frequency lifting and descending motions. A close examination of a few of the experiments will illustrate the erratic behavior and will show the futility of attempting to develop concise, accurate, quantitative statements of inhalation-level dosages resulting from diffusing puffs of the character under consideration here.

Figure 3 shows, for three experiments, the downwind distribution of peak dosages normalized for source strength. Each experiment was conducted under thermally unstable and relatively strong wind conditions, yet the downwind distributions are decidedly different. There is nothing in the meteorological statistics of the three to suggest that one should be any different from the other. Yet we see in one case, Experiment 23, a much greater decrease of dosage than would be expected after the puff has traversed about 1/3 the length of the sampling grid. In another, Experiment 31, the observed dilution rate is much less than would be expected. In Experiment 19 the dosages actually increase with distance over the outer half of the grid. The normalized arcwise integrated dosages shown in Figure 4 for the same experiments have similar downwind distributions. It is not likely that any prediction scheme based on measured meteorological parameters will ever be able to explain these anomalies. Unless they are adequately defined by meteorological measurements, there is little chance that inhalation-level dosages, observed under conditions prevailing for the Sand Storm experiments, can be predicted except on a statistical basis with but little reduction of variance gained through the use of meteorological measurements.

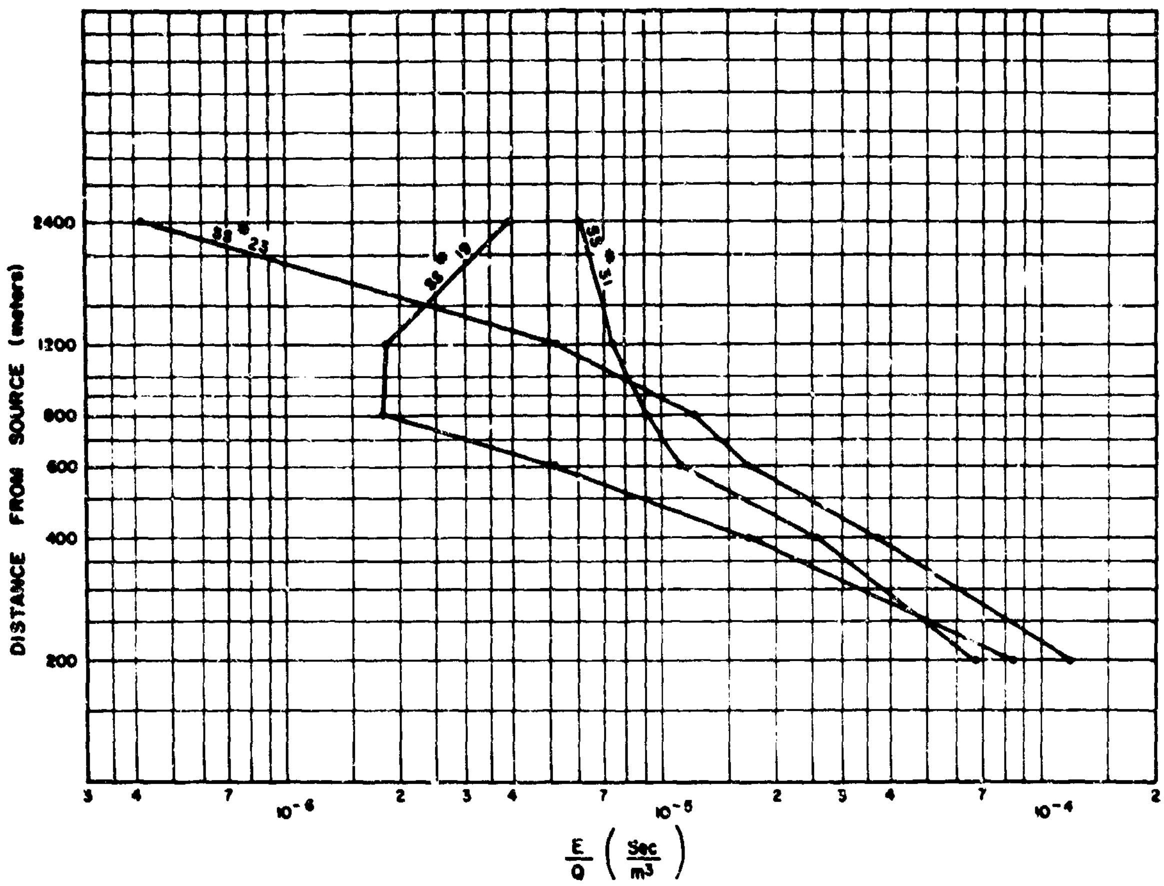

Figure 3. Downwind Distribution of Peak Dosages Normalized for Source Strength for Three Sand Storm Experiments Conducted Under Similar Meteorological Conditions

It should be recalled that all the Sand Storm experiments were conducted under thermally unstable conditions, which tends to limit the range of meteorological parameters. This is perhaps a partial explanation of the low correlations between the meteorological parameters and E_p/Q. Had tests also been conducted at night when thermally stable conditions prevailed, a greater range of meteorological parameters would have been observed. Correlations with E_p/Q most likely would have been greater, yielding a greater reduction of variance. Even then it is doubtful that operational applications of estimating equations could be made without resorting to some form of probability statement.

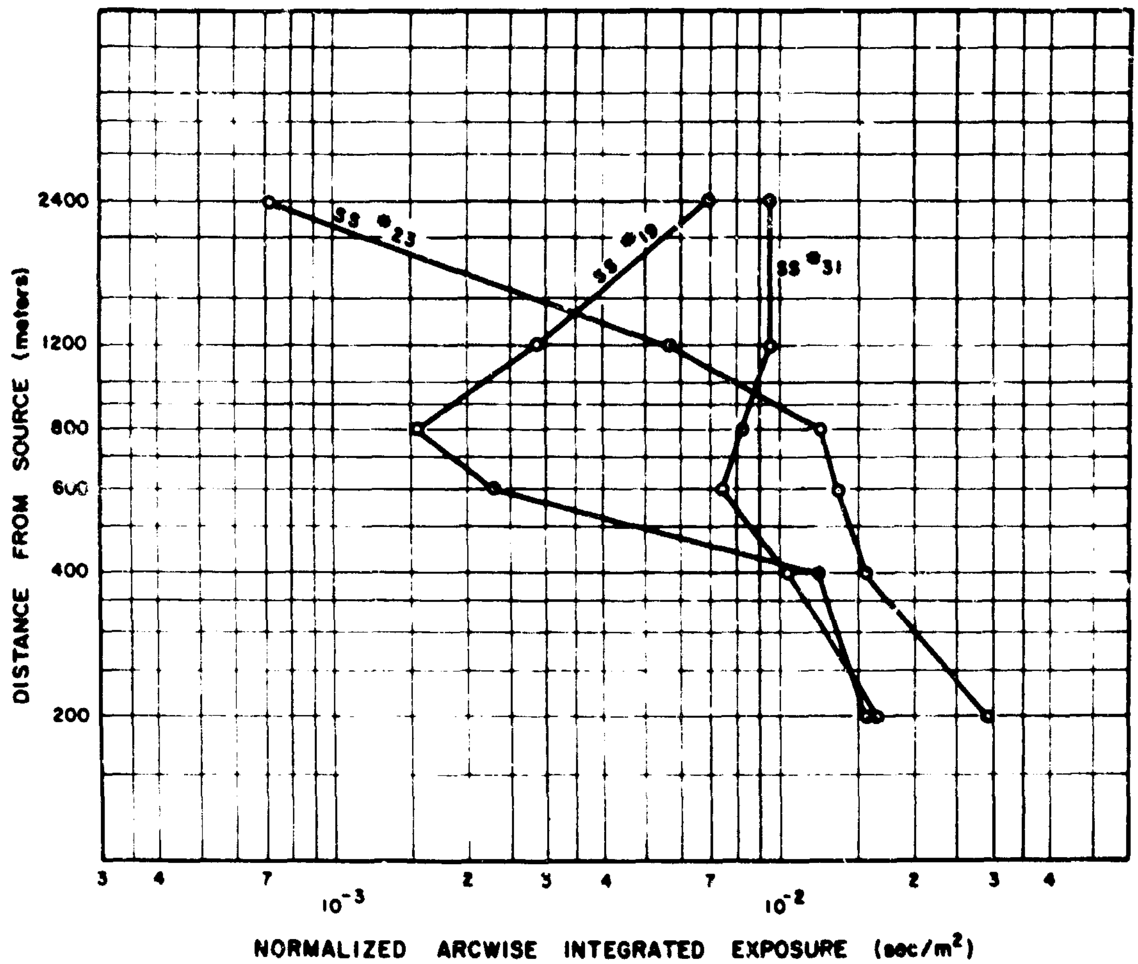

Figure 4. Downwind Distributions of Arcwise Integrated Dosages Normalized for Source Strength for Three Sand Storm Experiments Conducted Under Similar Meteorological Conditions

4. PROBABILITY ANALYSIS

Since most of the explained variance has been shown to be a function of distance from the source, we will develop a scheme for relating peak downwind exposures to travel distance as a function of probability of occurrence. No meteorological measurements are required, except to establish that thermally unstable conditions prevail over the region that the cloud is to travel and that a mean wind speed of at least 6 knots exists over the area (the general conditions prevailing during Sand Storm experiments).

Figure 5 shows a plot of E_p/Q vs. downwind distance for the 38 experiments for which we had reliable measurements of the peak dosage at all 5 of the outermost arcs. (See exception noted in Figure 5.) The E_p/Q values extend over about

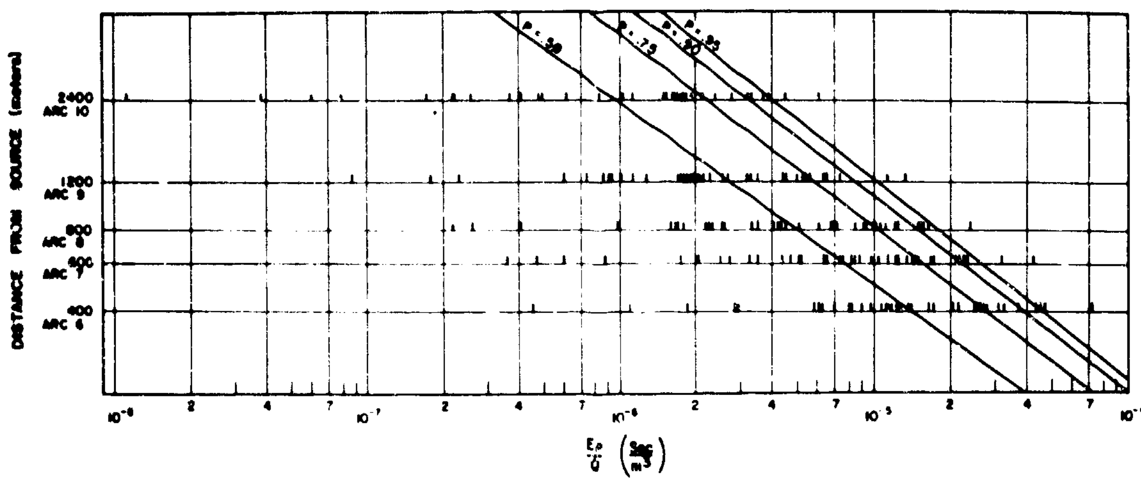

Figure 5. Normalized Peak Dosages Plotted as a Function of Distance for 38 Sand Storm Experiments. The lowest three values at the 2400-meter arc have been omitted. Those were for Experiment Nos. 18, 34, and 49 in which the amount of tracer collected was so low (< 0.5 microgram) that an accurate assay was not possible. The curves, P = .50, P = .75, P = .90, and P = .95, represent the probabilities (0.50, 0.75, 0.90, and 0.95, respectively) of not exceeding the indicated values

2 orders of magnitude at each travel distance. At each travel distance they appear to have a distribution not unlike the Gaussian when only the upper 70 percent of E_p/Q values are examined. Figure 6 shows, for the 800-meter arc, a plot on probability paper of E_p/Q values vs. the cumulative percentage of occurrence. The more closely the points are collinear the more closely the distribution approaches the Gaussian form. Fitting a straight line to the points yields a mean and a standard deviation for the Gaussian distribution approximated by the points. This was done by the method of least squares for all E_p/Q values exceeding the 30th percentile at each of the five travel distances. Regression analysis was then used to relate the computed mean and standard deviation to distance from the source, thus allowing the computation of regression lines relating E_p/Q to downwind distances for various probabilities of occurrence.

The regression line representing the 50th percentile was found to be:

$$\left(\frac{E_p}{Q}\right)_{50} = .116\,X^{-1.50} \tag{7}$$

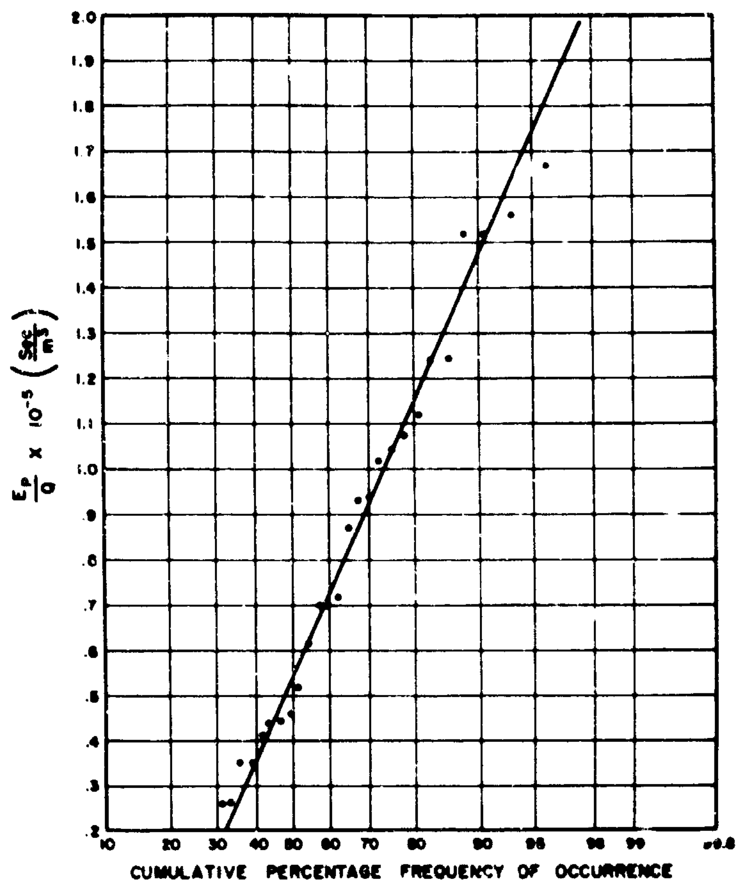

Figure 6. Distribution of Measured Values of E_p/Q at a Distance of 800 Meters from the Source

where $\left(\frac{E_p}{Q}\right)_{50}$ = the 50th percentile value of E_p/Q in units of seconds per cubic meter (Gaussian distribution assumed),

and X = the distance from the source in units of meters.

The standard deviation of the distribution of E_p/Q values, also a function of downwind travel distance, was found to be:

$$\sigma\left(\frac{E_p}{Q}\right) = .0626\ X^{-1.34} \tag{8}$$

where $\sigma\left(\frac{E_p}{Q}\right)$ = the standard deviation of E_p/Q values about their mean, in units of seconds per cubic meter,

and X = distance from the source in meters.

The curves in Figure 5 represent the 0.50, 0.75, 0.90, and 0.95 probability levels. This, of course, is no more than a quantitative description of the distribution of normalized peak dosages for the ensemble of Sand Storm diffusion experiments. However, it provides a simple procedure for evaluating the potential hazard associated with firing rocket motors of the type under consideration during thermally unstable atmospheric conditions.

Acknowledgments

The work reported in this chapter was conducted by a number of people. Among those especially active in the task were: Captain Juri V. Nou (AWS), Miss Joan Dwyer (AFCRL), and Miss Patricia Kelly (Regis College) who developed the computer routines used in the analyses and processed much of the data. Dr. M.L. Barad and Dr. D.A. Haugen devoted many hours of their time to discussions covering all aspects of the analyses. The author gratefully acknowledges the opportunity to document this effort.

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Appendix A

Dosage and Source Data

This appendix consists of three tables. Table A1 presents normalized dosage data for all valid Sand Storm experiments and a limited amount of meteorological data. Table A2 contains explanatory notes supplementing information shown in Table A1. Table A3 presents information concerning the tracer source.

In the heading of each tabulation in Table A1, U-BAR is the wind speed taken at 12 feet on the profile tower and averaged over a 10-minute period beginning 3 minutes before motor firing. DELTA T [1], DELTA T [2], and DELTA T [3] are the temperature differences between 6 feet and 50, 100, and 200 feet respectively. A negative value indicates a temperature decrease with height, thus an "unstable" condition. Also given in the headings are arc numbers and the distance in meters of the arc from the source. Azimuths are degrees (true) from the source point. Values shown in the body of the tabulations are dosage values normalized for source strength (sometimes referred to as normalized exposures) in units of 10^{-6} seconds per cubic meter. These values are derived by dividing the amount of tracer material collected at each sampling position by the aspiration rate of the sampling unit and by the amount of tracer released. Starred values indicate that there is some doubt as to the exact value shown, and a brief note explaining the circumstances of each starred dosage value is given in Table A2. At the foot of each tabulation in Table A1 the arcwise standard deviation is shown in degrees (SIGMA DEG:) and in meters (SIGMA M:) for all arcs with at least five significant measurements (that is, with five dosage measurements equal to or greater than 0.5μg Be) and a peak value of at least 5μg Be. For A.c 10 the peak dosage requirement was relaxed to 2.5μg Be.

Table A3 give information on motor size and firing duration. The times shown are for ballistic burn time which does not include a fraction of a second at the beginning and end of the firing sequence.

Table A1. Normalized Dosage Data

NORMALIZED DOSAGES

SAND STORM NO. 02
DATE 27 MAR 1963
TIME 1130 PST

E/Q

[10^{-6} SEC/CU METER]

U-BAR: 10.33 METERS/SEC
DELTA T [1]: -1.4 DEG F
DELTA T [2]: -1.6 DEG F
DELTA T [3]: -2.7 DEG F

ARC NO:	1	2	3	4	5	6	7	8	9	10
DIST[M]:	100	150	200	250	300	400	600	800	1200	2400
AZIMUTH										
45			0.374							
46										
47					0.374					
48										
49	2.32	1.47	1.02	1.12						
50					3.64	4.65				
51										0.524
52										0.449
53	46.2	49.4	44.9*	14.5	16.5	28.0	15.0	7.00	1.38	0.913
54										0.644
55									1.84	0.823
56					39.7	22.4	17.2	1.02		0.823
57	147.0	154.0	95.2	48.9					0.733	1.29
58										0.913
59					15.9	18.7	1.29	2.14	1.29	1.12
60										1.75
61	304.0	53.9	18.9	13.9						1.57
62					4.21	2.24	0.823	0.823		1.47
63										
64										
65	84.4	3.64	4.65							
66										
67										
68										
69	12.7	5.33								
70										
71										
72										
73	0.913									
SIGMA										
DEG:	3.53	3.18	2.91	**	2.74	2.91	**	**	**	**
M:	6.1	8.3	10.1	**	14.3	20.3	**	**	**	**

Table A1 (contd)

NORMALIZED DOSAGES

SAND STORM NO. 03
DATE 8 APR 1963
TIME 1040 PST

E/Q

[10^{-6} SEC/CU METER]

U-BAR: 11.00 METERS/SEC
DELTA T [1]: -1.6 DEG F
DELTA T [2]: -1.8 DEG F
DELTA T [3]: -2.5 DEG F

ARC NO:	1	2	3	4	5	6	7	8	9	10
DIST[M]:	100	150	200	250	300	400	600	800	1200	2400
AZIMUTH										
65				0.504	0.280*					
66										
67										
68					0.371	0.422	0.694			
69	16.8	2.63	1.23	0.586						
70										
71					0.616	1.43	0.828		0.151	
72										
73	161.0	38.9	15.4	10.0					0.259*	
74					6.64	10.5	2.48	0.422		
75									0.647*	
76										0.211
77	168.0	79.0	55.8	27.8	12.5*	11.2	6.90	2.16	2.50	0.259*
78										0.345*
79									3.13	0.478
80					19.9	19.7	6.90	3.40		0.293
81	49.4	47.1	34.2	30.0					0.862*	0.129
82										
83					14.3	16.8	14.0	3.32	0.431*	
84										
85	25.3	23.7	22.7	19.0					0.293	
86					5.52	2.26	2.07	0.108		
87										
88										
89	3.10	1.05	1.51	1.13	0.560	0.884	0.586			
90										
91										
92						0.293				
93		0.884		0.586						
SIGMA										
DEG:	3.84	4.05	3.91	4.24	3.83	3.93	4.05	**	**	**
M:	6.6	10.5	13.6	18.5	20.0	27.4	42.3	**	**	**

NORMALIZED DOSAGES

SAND STORM NO. 05
DATE 24 APR 1963
TIME 1531 PST

E/Q

[10^{-6} SEC/CU METER]

U-BAR: 5.86 METERS/SEC
DELTA T [1]: -2.0 DEG F
DELTA T [2]: -2.3 DEG F
DELTA T [3]: -3.0 DEG F

ARC NO:	1	2	3	4	5	6	7	8	9	10
DIST[M]:	100	150	200	250	300	400	600	800	1200	2400
AZIMUTH										
49	7.09	0.695	0.425							
50							2.13			
51										
52										
53	39.0	7.09*	22.3	17.0	9.70		2.84*			
54										
55									1.39	
56					19.1	9.92	3.90	0.964		
57	63.7	36.7	43.2	21.3					2.13	
58										
59					33.5	19.7	6.73	5.40	4.13	
60										
61	115.0	52.5	55.7	32.5					11.4	
62					35.2	25.0	17.6	13.8		
63									2.88	0.284*
64										0.354
65	216.0	203.0	104.0	43.2	49.6	41.1	43.2	24.1	4.25*	0.964
66										2.37
67									5.67*	2.13
68					74.6	45.4	43.2	20.7		1.66
69	373.0	140.0	68.1	58.4					10.8	1.39
70										2.55
71					32.9	15.9	17.0*	14.2	13.5	0.964
72										2.64
73	352.0	36.7	33.5	8.15					8.86	3.19
74					3.63	2.28	2.20	1.84		3.71
75									4.11	2.84*
76										2.13*
77	15.9				0.496	0.610	1.06		2.13*	1.57
78										1.22
79									1.53	2.03
80										0.496
81									1.18	1.30
82										0.142
83										0.142
84										0.865
85										1.22
SIGMA										
DEG:	5.58	4.31	5.52	5.56	5.06	4.32	4.55	3.83	5.94	5.30
M:	9.7	11.2	19.2	24.2	26.4	30.1	47.6	53.4	124.3	222.1

Table A1 (contd)

NORMALIZED DOSAGES

E/Q

[10^{-6} SEC/CU METER]

SAND STORM NO. 06
DATE 6 MAY 1963
TIME 1420 PST

U-BAR: 3.86 METERS/SEC
DELTA T [1]: -2.4 DEG F
DELTA T [2]: -2.8 DEG F
DELTA T [3]: -3.9 DEG F

ARC NO:	1	2	3	4	5	6	7	8	9	10
DIST[M]:	100	150	200	250	300	400	600	800	1200	2400
AZIMUTH										
59										0.351
60										0.974
61										0.351
62						1.15				0.974
63									1.07	1.51
64										0.308
65			0.537	0.394	0.537	1.79			0.881	0.179
66										0.215
67									0.881	0.0358
68					0.394	0.881	0.351			0.537
69	3.98		0.115	0.702					2.10	0.616
70										0.351
71					2.59	3.58	5.26	2.23	2.15	0.573
72										0.573
73	22.4	14.7	1.38	3.80					1.88	0.437
74					9.67	14.2	2.69	0.702		0.437
75									0.881	
76										
77	35.5	37.1	10.2	8.60	5.95	8.88	0.351	0.537	0.974	
78										
79									0.931	
80					19.1	8.31	0.394	0.179		
81	153.0	57.3	31.9	31.6						
82										
83					15.1*	1.25	0.351			
84										
85	240.0	139.0	34.9	24.6						
86					3.58		0.659			
87										
88										
89	106.0	12.2	0.215	0.115	0.659					
90										
91										
92					0.179					
93	5.16			0.351						
94										
95					0.251					
SIGMA										
DEG:	4.20	3.93	3.39	3.82	4.49	4.50	4.46	**	4.51	**
M:	7.3	10.2	11.8	16.6	23.5	31.4	46.6	**	94.4	**

Table A7 (cont'd)

NORMALIZED DOSAGES

SAND STORM NO. 07
DATE 8 MAY 1963
TIME 0939 PST

E/Q

[10^{-6} SEC/CU METER]

U-BAR: 7.58 METERS/SEC
DELTA T [1]: -2.2 DEG F
DELTA T [2]: -2.5 DEG F
DELTA T [3]: -3.6 DEG F

ARC NO:	1	2	3	4	5	6	7	8	9	10
DIST[M]:	100	150	200	250	300	400	600	800	1200	2400
AZIMUTH										
47					0.179	0.394				
48										
49	5.11	1.07	0.537	0.251						
50					0.251	0.537	0.251	0.487		
51										
52										
53	17.2	15.0	1.15	3.04	1.97	2.05	4.65	2.23	1.25	
54										
55									2.51	
56					12.2	17.2	5.66	5.66		
57	93.1*	29.5	23.5	22.9					3.04	
58										
59					21.5*	21.8	14.7	6.94	3.94	0.838
60										0.537
61	139.0	63.0	41.0	26.5					5.42	0.974
62					17.5	14.0	11.0	7.16		0.795
63									4.12	0.394
64										0.251
65	111.0	36.8	28.9	15.8	16.4	9.95	11.2	6.16	4.57	1.15
66										0.179
67									3.79	0.638
68					2.59	2.51	2.55	5.51		
69	44.4	8.31	5.66	2.19					3.76	
70										
71					0.308		0.537	0.437		
72										
73	2.86	0.881	2.77							
74					0.179					
75										
76										
77	0.881	0.251	0.659		0.179					
SIGMA										
DEG:	4.50	4.33	4.19	**	3.86	3.78	4.20	4.77	4.53	**
M:	7.8	11.3	14.6	**	20.2	26.3	43.9	66.6	94.9	**

Table A1 (cont'd)

NORMALIZED DOSAGES

SAND STORM NO. 09
DATE 23 MAY 1963
TIME 1311 PST

E/Q

[10^{-6} SEC/CU METER]

U-BAR: 9.14 METERS/SEC
DELTA T [1]: -3.1 DEG F
DELTA T [2]: -3.8 DEG F
DELTA T [3]: -4.8 DEG F

ARC NO:	1	2	3	4	5	6	7	8	9	10
DIST[M]:	100	150	200	250	300	400	600	800	1200	2400
AZIMUTH										
73	0.511	0.357								
74										
75										
76										
77	28.4	0.255	0.314			0.255				
78										
79									0.255	
80					0.445	0.810				
81	233.0	26.1	8.17	0.117					0.496	
82										
83					5.99	0.897			0.117	0.314
84										0.445
85	156.0	217.0	47.9	34.5					0.547	0.547
86					37.8	4.75	22.0	4.16		0.715
87									3.23	0.854
88										1.46
89	309.0	150.0	68.6	73.3	97.4	73.3	22.8	16.7	5.25	1.46
90										1.82
91									6.57	1.09
92					103.0	67.1	19.5	6.86		0.854
93	150.0	134.0	78.8	124.0					3.01	0.992
94										0.255
95					32.0	28.8	11.7	2.55	0.219	0.401
96										0.445
97	26.1	16.1	15.8	16.1					0.182	0.401
98					3.87	1.46	0.182			
99										
100										
101	0.496	0.897	1.82							
102										
103										
104										
105			0.584							
SIGMA										
DEG:	4.85	3.90	4.15	**	2.96	2.62	**	**	2.92	3.41
M:	8.4	10.2	14.4	**	15.5	18.2	**	**	61.2	142.9

Table A1 (contd)

NORMALIZED DOSAGES

E/Q

[10^{-6} SEC/CU METER]

SAND STORM NO. 10
DATE 29 MAY 1963
TIME 1352 PST

U-BAR: 6.16 METERS/SEC
DELTA T [1]: -2.5 DEG F
DELTA T [2]: -3.1 DEG F
DELTA T [3]: -4.2 DEG F

ARC NO:	1	2	3	4	5	6	7	8	9	10
DIST[M]:	100	150	200	250	300	400	600	800	1200	2400
AZIMUTH										
41	0.568									
42										
43										
44										
45	0.501									
46										
47										
48										
49	1.62	0.501								
50										
51										
52										
53	2.39	0.824								
54										
55										
56										
57	1.50	1.41		0.312						
58										
59					0.312		0.696			
60										
61	3.26	1.44	0.537	1.44						0.179
62					0.824	0.128	0.568			0.384
63										0.220
64										0.179
65	18.5	2.65	3.68	4.25	6.34	1.28	0.251	0.501		0.179
66										0.153
67									0.824	0.179
68					7.88	1.37	1.79	0.629		0.251
69	125.0	11.7	6.34	9.77					0.696	0.384
70										0.471
71					15.6	3.53	1.15	1.21	1.50	1.02
72										0.384
73	81.9	1.41	11.3	12.9					2.05	0.0819
74					6.75	7.11	1.02	1.66		0.153
75									0.665	0.384
76										0.220
77	0.895	1.24	4.40	1.66	3.33	1.59	0.885	1.11	0.348	0.128
78										0.568
79									0.179	0.767
80					1.11	1.46	0.225			0.312
81	0.629	0.854	0.537	0.312						
82										
83					0.696	0.409				
84										
85	0.501		0.179							
86						0.128				
SIGMA										
DEG:	4.22	6.44	4.28	4.12	4.26	4.28	5.72	**	**	**
M:	7.3	16.8	14.9	17.9	22.2	29.8	59.9	**	**	**

Table A1 (contd)

NORMALIZED DOSAGES

E/Q

[10^{-6} SEC/CU METER]

SAND STORM NO. 11
DATE 10 JUN 1963
TIME 0914 PST

U-BAR: 12.51 METERS/SEC
DELTA T [1]: -2.4 DEG F
DELTA T [2]: -2.5 DEG F
DELTA T [3]: -4.0 DEG F

ARC NO:	1	2	3	4	5	6	7	8	9	10
DIST[M]:	100	150	200	250	300	400	600	800	1200	2400
AZIMUTH										
45	0.127	0.178	0.249	0.437						
46										
47										
48										
49	0.467	0.0812	0.178	0.508					0.249	
50										
51									0.279	
52										
53	1.52	0.249	0.279	0.762*					0.249	
54										
55									0.234*	
56					0.624	0.249				
57	50.8	13.8	5.89	3.59					0.218	
58										
59					5.89	1.88	1.14		0.406	
60										
61	160.0	87.8	23.0	14.0					1.02	
62					15.3	9.34	3.87	0.660		0.127
63									2.16	0.249
64										0.624
65	321.0	265.0	101.0	55.1	31.0	16.7	6.60	4.57	2.28	1.23
66										1.40
67									1.90	1.14
68					9.90	9.14*	2.88	2.38		1.33
69	353.0	25.2	7.82	2.63					0.249	1.78
70										0.127
71					2.31	1.52	0.0508	0.127	0.279	0.152*
72										0.178
73	8.94	2.10	0.127	0.249					0.152	0.127
74						0.564	0.127			0.310
75									0.178	
76										
77	1.36	0.817	0.178	0.127		0.310				
78										
79										
80						0.178				
81	0.624	0.0812	0.249							
82										
83						0.127				
84										
85	0.594	0.127								
86						0.178				
87										
88										
89	0.381	0.0508				0.249				
90										
91										
92						0.310				
93	0.624	0.178								
SIGMA										
DEG:	3.87	2.77	2.77	3.69	2.89	4.73	**	**	5.07	**
M:	6.7	7.2	9.6	16.1	15.1	33.0	**	**	106.9	**

Table A1 (contd)

NORMALIZED DOSAGES
E/Q
[10^{-6} SEC/CU METER]

SAND STORM NO. 12
DATE 12 JUN 1963
TIME 1018 PST

U-BAR: 2.33 METERS/SEC
DELTA T [1]: -1.3 DEG F
DELTA T [2]: -1.7 DEG F
DELTA T [3]: -2.2 DEG F

ARC NO:	1	2	3	4	5	6	7	8	9	10
DIST[M]:	100	150	200	250	300	400	600	800	1200	2400
AZIMUTH										
17							0.127			
18										
19										
20							0.498			
21										
22										
23							0.279			
24										
25										
26							0.406			
27										
28										
29							0.178			
30										
31										
32					0.762	0.178	0.345			
33			0.152	0.975						
34										
35					4.14	0.345	0.467			
36										
37		0.310	3.05	3.31						
38					3.84	0.564	0.817			
39										
40										
41		0.127	3.08	5.13	4.33	1.45	0.762			
42										
43										
44					10.7	2.34	0.533			
45		3.05	1.14	18.1						
46										
47					14.4	9.90	0.762			
48										
49	2.10	1.20	1.58	22.6						
50					11.2	1.55	0.564			
51										
52										
53	3.24	1.17	3.76	33.5	15.9	1.07	0.381			
54										
55										
56					10.1	1.40	0.533			
57	7.11*	0.975	28.9	81.2						
58										
59					6.45	3.81	0.467		0.249	
60										
61	11.4	2.89	5.13	4.26					0.249	
62					7.31	2.85	2.79	0.533		
63									0.381	
64										0.218
65	47.2	15.1	2.89	15.1	10.3	1.84	2.69	1.61	0.406	0.127
66										0.279
67									0.888	0.437
68					16.3	1.75	2.59	1.14		0.533
69	215.0	8.83	15.5	17.3					1.52	0.345
70										0.660
71					9.90	2.34	1.96	0.178	1.88	0.406
72										0.564
73	166.0	18.5	19.6	26.6					1.71	0.690
74					2.72	2.47	1.07	0.0508		0.624
75									0.406	0.660
76										0.467

Table A1 (contd)

SAND STORM NO. 12 [CONT.]

ARC NO:	1	2	3	4	5	6	7	8	9	10
DIST[M]:	100	150	200	250	300	400	600	800	1200	2400
AZIMUTH										
77	30.3	11.6	11.6	19.5	2.44	3.40	1.02	0.345		0.660
78										0.467
79										0.848
80					0.888	1.78	0.690	0.127		0.564
81	27.2	8.12	24.2	12.0						0.624
82										0.762
83					0.564	1.45	0.381	0.279		0.178
84										
85	27.2	11.6	15.5	5.33						
86					0.437	1.04	0.498	0.0508		
87										
88										
89	6.85	4.26	9.04	0.690		0.726	0.381	0.381		
90										
91										
92						0.690	0.533	0.249		
93	7.72	2.16	8.12	0.381						
94										
95						0.660	0.249			
96										
97	20.9			0.152						
98						0.467	0.564			
99										
100										
101	15.9					1.02	0.594			
102										
103										
104						1.07	0.594			
105	0.624									
106										
107						0.564	0.345			
SIGMA										
DEG:	9.07	10.6	13.6	11.5	11.2	17.8	20.1	**	17.9	**
M:	15.8	27.8	47.5	50.1	53.7	124.3	210.9	**	375.3	**

NORMALIZED DOSAGES

SAND STORM NO. 13
DATE 14 JUN 1963
TIME 1057 PST

E/Q

[10^{-6} SEC/CU METER]

U-BAR: 2.91 METERS/SEC
DELTA T [1]: -1.7 DEG F
DELTA T [2]: -2.1 DEG F
DELTA T [3]: -2.8 DEG F

ARC NO:	1	2	3	4	5	6	7	8	9	10
DIST[M]:	100	150	200	250	300	400	600	800	1200	2400
AZIMUTH										
44						0.108				
45										
46										
47						0.130				
48										
49				2.22						
50					0.698	0.373				
51										
52										
53				2.74	2.77	0.867	0.108			
54										
55										
56					2.82	1.27	0.152			
57		0.590		1.14						
58										
59					1.63	1.68	0.672	0.130	0.238	
60										
61		1.33	0.130	0.373					0.507	
62					1.08	3.59	1.63	0.915		
63									0.806	0.212
64										0.186
65		**	0.455	2.49	2.63	4.77	2.82	4.38	0.425	0.108
66										0.0434
67									0.295	**
68					5.16	4.03	6.24	3.64		0.108
69	1.57	**	2.19	3.18					0.650	0.130
70										**
71					2.43	5.51	7.72	4.21	0.832	0.108
72										0.130
73	6.24	0.186	8.45	6.24					1.30	0.212
74					3.31	6.24	7.54	2.22		0.347
75									1.19	0.373
76										
77	3.04	0.325	4.77	1.68	2.28	5.33	8.63	1.68	1.95	
78										
79									1.52	
80					1.24	3.25	9.93	2.93		
81		0.590	1.95	0.780					1.37	
82										
83					0.915	3.01	5.51	3.72	1.44	
84										
85		0.533	2.28	0.425					1.95	
86					0.698	1.95	2.93	2.00		
87									1.89	
88										
89			0.186	0.915	0.212	0.212	0.325	1.41	2.11	
90										
91									2.60	
92					0.425	0.152	0.264	0.533		
93			0.152	0.832					1.98	
94										
95					0.325	0.212	0.212	0.373	2.17	
96										
97				0.698					1.68	
98					0.264	0.186				
99									1.46	
100										
101				0.481	0.425				0.425	
102										
103										
104					0.264					
105				0.186						
106										
107					0.238					
SIGMA										
DEG:	**	**	5.37	13.4	12.0	8.90	6.74	8.46	10.3	**
M:	**	**	18.7	58.4	63.0	62.1	70.6	118.1	215.7	**

Table A1 (contd)

NORMALIZED DOSAGES

E/Q

[10^{-6} SEC/CU METER]

SAND STORM NO. 14
DATE 19 JUN 1963
TIME 1018 PST

U-BAR: 5.31 METERS/SEC
DELTA T [1]: -1.8 DEG F
DELTA T [2]: -2.6 DEG F
DELTA T [3]: -3.4 DEG F

ARC NO:	1	2	3	4	5	6	7	8	9	10
DIST[M]:	100	150	200	250	300	400	600	800	1200	2400
AZIMUTH										
71								0.216		
72										
73										
74								0.0718		
75										
76										
77	0.704						0.352	0.352		
78										
79										0.216
80							0.438	0.180		0.251
81	33.5	0.180								0.884
82										0.661
83						0.489	1.34	1.08	0.884	0.180
84										
85	69.7	30.5	0.661						1.80	
86					0.251	0.797	3.23	4.40		0.251
87									2.74	1.34
88										2.10
89	158.0	33.8	10.3	6.03	1.88	1.11	3.52*	0.884	1.52	2.05
90										2.16*
91									0.352	2.16
92					4.31		0.977	0.180		0.352
93	53.9	31.7	19.8	10.9					0.216	0.309
94										0.180
95					2.69		0.704			
96										
97	5.94	10.3	10.6	2.05						
98					0.704		0.359			
99										
100										
101	1.16	0.618	0.618	0.251			0.216			
102										
103										
104										
105	0.438		0.251							
SIGMA										
DEG:	3.79	**	**	**	**	**	**	**	**	**
M:	6.6	**	**	**	**	**	**	**	**	**

Table A1 (contd)

NORMALIZED DOSAGES

SAND STORM NO. 16		E/Q		U-BAR:	4.47 METERS/SEC
DATE 9 JUL 1963		(10^{-6} SEC/CU METER)		DELTA T (1):	-1.6 DEG F
TIME 0950 PST				DELTA T (2):	-2.2 DEG F
				DELTA T (3):	-2.7 DEG F

ARC NO:	3	6	7	8	9	10
DIST(M):	200	400	600	800	1200	2400
AZIMUTH						
85.0	2.01*					
85.5						
86.0						0.518
86.5						
87.0	5.56	0.140				1.34
87.5						
88.0						3.27
88.5						
89.0	5.93	1.22	0.285			2.74
89.5						
90.0						2.10*
90.5						
91.0	4.72	0.374	0.350			1.57
91.5						
92.0						0.117
92.5						
93.0	8.87	0.490	1.55			
93.5						
94.0						
94.5						
95.0	11.1	1.45	4.72	1.48		
95.5						
96.0						
96.5				3.97*	0.934	
97.0	14.5	2.57	10.7			
97.5						
98.0				10.3	0.934	
98.5						
99.0	17.5	5.75*	19.8			
99.5				6.91	0.518	
100.0						
100.5						
101.0	33.1	12.5	23.6	15.2	0.575	
101.5						
102.0						
102.5				11.4	0.514*	
103.0	23.0	6.54*	2.66			
103.5						
104.0				0.668	0.458	
104.5						
105.0	16.6	3.92	0.701			
105.5						
106.0						
106.5						
107.0	5.93	0.897				
SIGMA						
DEG:	**	**	2.45	2.13	**	1.42
M:	**	**	25.6	29.6	**	59.5

Table A1 (contd)

NORMALIZED DOSAGES

SAND STORM NO. 17
DATE 11 JUL 1963
TIME 0933 PST

E/Q

[10^{-6} SEC/CU METER]

U-BAR: 5.37 METERS/SEC
DELTA T [1]: -1.7 DEG F
DELTA T [2]: -2.2 DEG F
DELTA T [3]: -3.0 DEG F

ARC NO:	3	6	7	8	9	10
DIST[M]:	200	400	600	800	1200	2400
AZIMUTH						
74.0						0.234
74.5						
75.0						0.263
75.5						
76.0						0.234
76.5						
77.0						
77.5						
78.0						
78.5						
79.0	0.358					
79.5						
80.0					0.234	
80.5						
81.0	32.2		0.530			
81.5				0.292	0.134*	
82.0						
82.5						
83.0	12.1	1.08	2.60	1.01		
83.5						
84.0						
84.5				2.32		
85.0	13.8	0.889	3.80			
85.5						
86.0				2.18		
86.5						
87.0	4.83	1.22	7.46			
87.5				2.60		
88.0						
88.5						
89.0	3.78	2.93	2.44	2.39		
89.5						
90.0						
90.5				1.70		
91.0		0.741	1.08			
91.5						
92.0						
92.5						
93.0		0.143				
SIGMA						
DEG:	2.45	**	2.30	2.46	**	**
M:	8.5	**	24.0	34.3	**	**

Table A1 (contd)

NORMALIZED DOSAGES

SAND STORM NO. 18
DATE 15 JUL 1963
TIME 1030 PST

E/Q

[10^{-6} SEC/CU METER]

U-BAR: 8.65 METERS/SEC
DELTA T [1]: -2.2 DEG F
DELTA T [2]: -2.7 DEG F
DELTA T [3]: -0.0 DEG F

ARC NO:	3	6	7	8	9	10
DIST[M]:	200	400	600	800	1200	2400
AZIMUTH						
56.0					0.453	
56.5						
57.0	42.3	0.913				
57.5					0.371*	
58.0						
58.5						
59.0	50.6	1.71	2.12	2.60	0.312*	
59.5						
60.0						
60.5				1.20	0.260	
61.0	51.2	23.3	2.87			
61.5						
62.0				1.20	1.30	
62.5						
63.0	88.0	25.3*	4.79			
63.5				1.43	0.557	
64.0						
64.5						
65.0	57.9	10.0	3.24	1.06	0.646	
65.5						
66.0						
66.5					0.728	
67.0	20.8*	2.69				
67.5						
68.0						
68.5						
69.0	7.20	1.00*				
69.5						
70.0						
70.5						
71.0		0.364				
71.5						
72.0						
72.5						
73.0		0.201*				
SIGMA						
DEG:	3.10	2.26	**	**	**	**
M:	10.8	15.7	**	**	**	**

Table A1 (contd)

NORMALIZED DOSAGES

SAND STORM NO. 19
DATE 17 JUL 1963
TIME 0936 PST

C/Q

[10^{-6} SEC/CU METER]

U-BAR: 12.60 METERS/SEC
DELTA T [1]: -2.1 DEG F
DELTA T [2]: -2.6 DEG F
DELTA T [3]: -3.9 DEG F

ARC NO:	3	6	7	8	9	10
DIST(M):	200	400	600	800	1200	2400
AZIMUTH						
67.0	0.270					
67.5						
68.0						
68.5						
69.0	4.73					
69.5						
70.0						
70.5						
71.0	17.0	5.56	0.378		1.20	
71.5						
72.0						
72.5				1.82	1.88	
73.0	53.6	17.3	5.22			0.579
73.5						
74.0				1.78	1.74	3.71
74.5						
75.0	84.9	7.80	2.51			3.94
75.5				1.00	1.29	
76.0						3.19
76.5						
77.0	17.3	3.86	0.471	0.811	0.525	1.54
77.5						
78.0						
78.5				0.332	0.378	
79.0	3.90	0.949	0.193			
79.5						
80.0					0.193	
SIGMA						
DEG:	1.92	1.92	**	**	2.39	**
M:	6.7	13.4	**	**	50.0	**

Table A1 (contd)

NORMALIZED DOSAGES

SAND STORM NO. 20 — DATE 26 JUL 1963 — TIME 1018 PST

E/Q

[10^{-6} SEC/CU METER]

U-BAR: 3.86 METERS/SEC
DELTA T [1]: -0.7 DEG F
DELTA T [2]: -2.3 DEG F
DELTA T [3]: -2.8 DEG F

ARC NO:	3	6	7	8	9	10
DIST[M]:	200	400	600	800	1200	2400
AZIMUTH						
54.0						0.0836
54.5						
55.0						0.142
55.5						
56.0						0.140
56.5						
57.0						0.201
57.5						
58.0						0.435
58.5						
59.0						0.414
59.5						
60.0						0.414
60.5						
61.0						0.418*
61.5						
62.0						0.421
62.5						
63.0	1.35					0.304
63.5						
64.0						0.496*
64.5						
65.0	6.30					0.836
65.5						
66.0						0.659
66.5						
67.0	6.02*					0.949
67.5						
68.0						0.797
68.5						
69.0	5.66					1.42
69.5					0.204	
70.0						1.59
70.5						
71.0	15.0				0.358	0.949
71.5						
72.0						1.35
72.5					0.230	
73.0	24.4					1.57
73.5						
74.0					0.262	1.61
74.5						
75.0	1.50					1.72
75.5					0.179	
76.0						1.50
76.5						
77.0	0.659				0.122	0.974
77.5						
78.0						1.24
78.5					0.708*	
79.0	0.531					0.995
79.5						
80.0				2.61	2.65	0.347
80.5						
81.0	0.443	0.244	1.95			0.995
81.5				15.6	2.40	
82.0						1.33
82.5						
83.0	0.372	1.27	1.63	13.4	3.29*	0.974
83.5						

Table A1 (contd)

SAND STORM NO. 20 [CONT.]

ARC NO:	3	6	7	8	9	10
DIST[M]:	200	400	600	800	1200	2400
AZIMUTH						
84.0						0.570
84.5				12.6	4.50	
85.0		0.297	1.35			0.241
85.5						
86.0				6.37*	4.21	0.188
86.5						
87.0		0.297	2.08			0.146
87.5				3.43	1.95	
88.0						0.104
88.5						
89.0		0.177	4.50	3.72	1.45*	0.0797
89.5						
90.0						0.0482
90.5				2.14	1.14	
91.0			2.26			0.0531
91.5						
92.0				1.73	1.05	0.0747
92.5						
93.0			0.673			
93.5				0.974	0.867	
94.0						
94.5						
95.0				0.705	0.811	
95.5						
96.0						
96.5				1.04	0.464	
97.0						
97.5						
98.0				0.779	0.110	
98.5						
99.0						
99.5				1.27		
SIGMA						
DEG:	3.37	**	3.56	4.30	5.13	7.32
M:	11.7	**	37.2	60.0	107.5	306.7

Table A1 (contd)

NORMALIZED DOSAGES

SAND STORM NO. 21	E/Q	U-BAR: 7.57 METERS/SEC
DATE 30 JUL 1963	$[10^{-6}$ SEC/CU METER]	DELTA T [1]: -1.2 DEG F
TIME 1256 PST		DELTA T [2]: -3.6 DEG F
		DELTA T [3]: -4.6 DEG F

ARC NO:	3	6	7	8	9	10
DIST[M]:	200	400	600	800	1200	2400
AZIMUTH						
65.0	0.110		0.117	0.106		
65.5						
66.0						
66.5				0.163		
67.0	0.203	0.152	0.256			
67.5						
68.0				0.156		
68.5						
69.0	1.94	0.579	0.448			
69.5				0.241	0.156	
70.0						
70.5						
71.0	7.17	1.59*	0.833	0.459*	0.297	0.0766
71.5						
72.0						0.141
72.5				0.858	0.777	
73.0	11.7	4.48	5.79			0.191*
73.5						
74.0				1.54	1.38*	0.259
74.5						
75.0	71.7	17.7	9.28			0.833
75.5				3.25*	2.44	
76.0						1.65
76.5						
77.0	126.0	25.7	11.8	6.71	2.47	0.826
77.5						
78.0						0.851
78.5				9.43	4.48	
79.0	82.6	32.8	13.8			0.971
79.5						
80.0				12.4	4.62	1.09
80.5						
81.0	14.4	11.7	13.3			1.11*
81.5				9.14	5.65	
82.0						1.14
82.5						
83.0	2.82	4.06*	5.08	2.29	4.20	0.717
83.5						
84.0						0.191*
84.5				0.865	0.865	
85.0	0.636*	1.47	0.826			
85.5						
86.0				0.0946	0.177*	
86.5						
87.0		0.0812	0.177			
SIGMA						
DEG:	2.24	2.74	3.36	2.88	3.22	2.95
M:	7.8	19.1	35.1	40.2	67.3	123.7

Table A1 (contd)

NORMALIZED DOSAGES

E/Q

[10^{-6} SEC/CU METER]

SAND STORM NO. 22
DATE 9 AUG 1963
TIME 1458 PST

U-BAR: 4.33 METERS/SEC
DELTA T [1]: -2.0 DEG F
DELTA T [2]: -2.7 DEG F
DELTA T [3]: -3.5 DEG F

ARC NO:	3	6	7	8	9	10
DIST[M]:	200	400	600	800	1200	2400
AZIMUTH						
80.0				0.0894		
80.5						
81.0	2.08		0.223			
81.5				0.210		
82.0						
82.5						
83.0	1.51		1.31	0.622		
83.5						
84.0						
84.5				0.217		
85.0	1.10		1.62			0.0733
85.5						
86.0				0.199		0.105
86.5						
87.0	2.26	0.321	2.79			0.168
87.5				0.531		
88.0						0.105
88.5						
89.0	2.47	1.48	5.31	0.499	0.0915	0.0936
89.5						
90.0						0.0824
90.5				0.562	0.0562	
91.0	4.16	12.9	5.59			0.0716
91.5						
92.0				0.849	0.0349	0.0611
92.5						
93.0	4.30	3.32*	7.09			0.0524
93.5				1.31	0.0559	
94.0						0.109
94.5						
95.0	3.53*	0.824	8.56	2.44	0.0821	0.102
95.5						
96.0						0.0737
96.5				4.16	0.122	
97.0	2.93	2.32	10.1			0.0524
97.5						
98.0				6.46	0.894	0.138
98.5						
99.0	2.71	2.27	10.7			0.175
99.5				6.81	1.75	
100.0						0.102
100.5						
101.0	1.99	2.98	8.28	8.87	1.59	0.131
101.5						
102.0						
102.5				11.2	1.92	
103.0	2.68	1.64*	6.64			
103.5						
104.0				4.16	0.279	
104.5						
105.0	8.87	0.786	7.37			
105.5				3.39	0.262	
106.0						
106.5						
107.0	10.4	1.70	8.73	1.63		
SIGMA						
DEG:	**	**	**	**	**	**
M:	**	**	**	**	**	**

Table A1 (contd)

NORMALIZED DOSAGES

SAND STORM NO. 23
DATE 16 AUG 1963
TIME 1558 PST

E/Q

[10^{-6} SEC/CU METER]

U-BAR: 7.45 METERS/SEC
DELTA T [1]: -2.6 DEG F
DELTA T [2]: -2.7 DEG F
DELTA T [3]: -3.6 DEG F

ARC NO:	3	6	7	8	9	10
DIST[M]:	200	400	600	800	1200	2400
AZIMUTH						
55.0		0.100				
55.5						
56.0						
56.5						
57.0	0.139	0.562	0.474			
57.5				0.386		
58.0						
58.5						
59.0	1.09	2.02	1.01	0.909		
59.5						
60.0						
60.5				0.966	0.386	
61.0	2.79	2.32	2.32			
61.5						
62.0				1.86	0.997	
62.5						
63.0	18.8	3.86	3.86			
63.5				3.27	1.60	
64.0						
64.5						
65.0	22.1	9.83	5.34	6.25	1.76	
65.5						
66.0						
66.5				7.90	1.55	
67.0	34.1	13.1	17.3			
67.5						
68.0				10.3	2.70	
68.5						
69.0	106.0	17.7	17.1			0.134
69.5				12.4	5.34	
70.0						0.239
70.5						
71.0	121.0	37.7	10.7	10.1	2.97	0.418
71.5						
72.0						0.171
72.5				7.72	2.02	
73.0	104.0	23.7	10.6			0.284
73.5						
74.0				3.86	1.40	0.266
74.5						
75.0	69.9	20.0	7.41			0.244
75.5				5.34	1.47	
76.0						0.279
76.5						
77.0	53.4	13.2	9.23	7.13	1.71	0.177
77.5						
78.0						
78.5				0.702	0.474	
79.0	14.9	6.35	1.18			
79.5						
80.0				0.0702		
80.5						
81.0	7.72	0.302	0.421			
81.5						
82.0						
82.5						
83.0	2.51		0.151			
83.5						
84.0						
84.5						
85.0	0.0878					
SIGMA						
DEG:	3.96	4.36	4.55	4.36	4.27	**
M:	13.8	30.4	47.6	60.8	89.5	**

Table A1 (contd)

NORMALIZED DOSAGES

E/Q

[10^{-6} SEC/CU METER]

SAND STORM NO. 24
DATE 19 AUG 1963
TIME 1542 PST

U-BAR: 5.82 METERS/SEC
DELTA T [1]: -1.3 DEG F
DELTA T [2]: -1.4 DEG F
DELTA T [3]: -2.3 DEG F

ARC NO:	3	6	7	8	9	10
DIST[M]:	200	400	600	800	1200	2400
AZIMUTH						
75.0	0.252	0.291	0.257			
75.5				0.0809		
76.0						
76.5						
77.0	0.989	0.647	0.608	0.0848		
77.5						
78.0						
78.5				0.193		
79.0	2.20	1.57	0.442			
79.5						
80.0				0.428		
80.5						
81.0	5.00	3.78	0.899			
81.5				0.324*	0.0719	
82.0						
82.5						
83.0	11.9	6.08	2.82	0.219	0.0899	
83.5						
84.0						
84.5				0.539	0.112	
85.0	19.6	8.05	3.63			
85.5						
86.0				1.77	0.264	0.261
86.5						
87.0	37.8	5.14	4.85			0.360*
87.5				2.23	0.608	
88.0						0.485
88.5						
89.0	42.8	9.20	6.08	2.37	1.19	0.205
89.5						
90.0						
90.5				5.32	2.02	
91.0	36.0*	3.31	7.73			
91.5						
92.0				7.59	1.74	
92.5						
93.0	30.2	6.29	6.65			
93.5				10.1	1.83	
94.0						
94.5						

Table A1 (contd)

SAND STORM NO. 24 [CONT.]

ARC NO:	3	6	7	8	9	10
DIST[M]:	200	400	600	800	1200	2400
AZIMUTH						
95.0	42.3	5.75	8.99	7.91	0.640	
95.5						
96.0						
96.5				4.85		
97.0	25.3	11.3	4.10			
97.5						
98.0				4.28		
98.5						
99.0	13.7	11.0	2.73			
99.5				1.30		
100.0						
100.5						
101.0	2.05	2.70	2.19			
101.5						
102.0						
102.5						
103.0	0.759	0.0942	1.04			
103.5						
104.0						
104.5						
105.0	0.0848	0.243	0.182			
105.5						
106.0						
106.5						
107.0			0.103			
SIGMA						
DEG:	4.81	6.48	5.57	4.03	**	**
M:	16.7	45.2	58.3	56.3	**	**

Table A1 (contd)

NORMALIZED DOSAGES

E/Q

[10^{-6} SEC/CU METER]

SAND STORM NO. 25
DATE 21 AUG 1963
TIME 1334 PST

U-BAR: 7.82 METERS/SEC
DELTA T [1]: -2.7 DEG F
DELTA T [2]: -3.2 DEG F
DELTA T [3]: -4.5 DEG F

ARC NO:	3	6	7	8	9	10
DIST[M]:	200	400	600	800	1200	2400
AZIMUTH						
63.0	0.0327					
63.5						
64.0						
64.5						
65.0	0.141					
65.5						
66.0						
66.5						
67.0	0.345					
67.5						
68.0						
68.5						
69.0	0.851*	0.0450				
69.5						
70.0						
70.5						
71.0	3.75	0.327	0.0450		0.0419	
71.5						
72.0						
72.5					0.0878	
73.0	8.92	0.593	0.860			0.0796
73.5						
74.0				0.583	0.180	
74.5						
75.0	15.9	4.58	1.65			
75.5				1.00	0.786	
76.0						
76.5						
77.0	24.9	6.06	2.55	0.565	0.876	
77.5						
78.0						
78.5				0.442*	0.933	
79.0	21.4	8.37	1.95			
79.5						
80.0				0.377	0.548	
80.5						
81.0	44.4	11.4	1.59			
81.5				0.0409	0.416	
82.0						
82.5						
83.0	33.2	6.55	0.123		0.262	
83.5						
84.0						
84.5					0.138	
85.0	14.6	1.35	0.0532			
85.5						
86.0					0.0429	
86.5						
87.0	6.19	0.0450	0.0480			
87.5						
88.0						
88.5						
89.0	0.612					
89.5						
90.0						
90.5						
91.0	0.0542					
SIGMA						
DEG:	3.89	2.92	2.71	**	2.88	**
M:	13.5	20.4	28.3	**	60.2	**

Table A1 (contd)

NORMALIZED DOSAGES

SAND STORM NO. 26
DATE 22 AUG 1963
TIME 1430 PST

E/Q

[10^{-6} SEC/CU METER]

U-BAR: 9.66 METERS/SEC
DELTA T [1]: -2.7 DEG F
DELTA T [2]: -3.0 DEG F
DELTA T [3]: -4.5 DEG F

ARC NO:	3	6	7	8	9	10
DIST[M]:	200	400	600	800	1200	2400
AZIMUTH						
49.0	0.212					
49.5						
50.0						
50.5						
51.0	4.11					
51.5						
52.0						
52.5						
53.0	12.6	0.0424				
53.5						
54.0						
54.5						
55.0	17.0	0.648	0.139			
55.5						
56.0				0.534		
56.5						
57.0	34.2	9.49	2.06			
57.5				0.939		
58.0						
58.5						
59.0	48.1	44.5	12.1	1.24	1.78	
59.5						
60.0						0.0818
60.5				5.77	1.46*	
61.0	61.9	42.6	17.8			0.259
61.5						
62.0				7.13*	1.25	0.246
62.5						
63.0	54.3	41.1	21.9			0.468
63.5				8.66	3.56	
64.0						0.426*
64.5						
65.0	64.8	30.0	12.8	5.34	2.92*	0.494
65.5						
66.0						0.591
66.5				6.87	2.59	
67.0	66.7	21.9	10.7			0.494
67.5						
68.0				5.51	2.40	0.632
68.5						
69.0	34.8	17.8	9.23			0.518*
69.5				2.74	1.51	
70.0						0.411
70.5						
71.0	28.8	15.7	5.04	2.06	1.21	0.219
71.5						
72.0						0.246
72.5				2.59	0.546	
73.0	20.6	9.23	4.34			0.178
73.5						
74.0				2.11	0.850	0.164
74.5						
75.0	8.60	4.53	3.29			0.113
75.5				1.78	0.454*	
76.0						0.0923
76.5						
77.0	6.80	2.88	0.769	0.453	0.233	0.0424
77.5						
78.0						
78.5				0.121	0.0504	

Table A1 (contd)

SAND STORM NO. 26 [CONT.]

ARC NO:	3	6	7	8	9	10
DIST[M]:	200	400	600	800	1200	2400
AZIMUTH						
79.0	0.769	0.382	0.139			
79.5						
80.0				0.206	0.0486	
80.5						
81.0	0.546	0.0850	0.0567			
81.5				0.0445		
82.0						
82.5						
83.0	0.121	0.0688		0.274		
83.5						
84.0						
84.5				0.121		
85.0	0.211	0.0424				
85.5						
86.0				0.0583		
86.5						
87.0	0.0794					
87.5						
88.0						
88.5						
89.0	0.0909					
89.5						
90.0						
90.5						
91.0	0.0342					
SIGMA						
DEG:	5.59	4.76	4.57	4.95	4.38	3.86
M:	19.5	33.2	47.9	69.0	91.6	161.6

Table A1 (contd)

NORMALIZED DOSAGES

E/Q

[10^{-6} SEC/CU METER]

SAND STORM NO. 27
DATE 27 AUG 1963
TIME 1538 PST

U-BAR: 6.35 METERS/SEC
DELTA T [1]: -1.8 DEG F
DELTA T [2]: -2.1 DEG F
DELTA T [3]: -2.9 DEG F

ARC NO:	3	6	7	8	9	10
DIST[M]:	200	400	600	800	1200	2400
AZIMUTH						
51.0	0.0863					
51.5						
52.0						
52.5						
53.0	0.263	0.202				
53.5						
54.0						
54.5						
55.0	1.29	0.452	0.113			
55.5						
56.0				0.0822		0.0470
56.5						
57.0	2.78	2.63	0.986			0.352
57.5				0.265	*0.0493	
58.0						0.846
58.5						
59.0	13.3	8.79	4.03	2.09	0.353	1.22*
59.5						
60.0						1.66
60.5				5.16	0.838	
61.0	29.3	9.04	7.61			1.25
61.5						
62.0				0.799	1.01	0.855*
62.5						
63.0	93.7	4.70	3.76			0.600
63.5				0.689	0.115	
64.0						0.417
64.5						
65.0	57.2	2.55	*0.0616	0.197*		0.565
65.5						
66.0						0.536
66.5				0.0616		
67.0	51.6	0.0717				0.475
67.5						
68.0						0.304
68.5						
69.0	26.3					0.100
69.5						
70.0						
70.5						
71.0	1.08					
71.5						
72.0						
72.5						
73.0	0.0657					
73.5						
74.0						
74.5						
75.0	0.0544					
75.5						
76.0						
76.5						
77.0	0.0431					
77.5						
78.0						
78.5						
79.0	0.0329					
SIGMA						
DEG:	2.83	2.41	**	1.57	**	3.07
M:	9.8	16.8	**	21.8	**	128.6

Table A1 (contd)

NORMALIZED DOSAGES

E/Q

[10^{-6} SEC/CU METER]

SAND STORM NO. 28
DATE 30 AUG 1963
TIME 1439 PST

U-BAR: 8.49 METERS/SEC
DELTA T [1]: -2.5 DEG F
DELTA T [2]: -2.8 DEG F
DELTA T [3]: -3.7 DEG F

ARC NO:	3	6	7	8	9	10
DIST[M]:	200	400	600	800	1200	2400
AZIMUTH						
55.0	0.0555					
55.5						
56.0						
56.5						
57.0	0.0905					
57.5						
58.0						
58.5						
59.0	0.132					
59.5						
60.0						
60.5						
61.0	0.202					
61.5						
62.0						
62.5						
63.0	0.782					
63.5						
64.0						
64.5						
65.0	2.50	0.0411				
65.5						
66.0						
66.5						
67.0	4.61*	0.142				
67.5						
68.0						
68.5						
69.0	8.97	2.70	0.0782			
69.5						
70.0						
70.5						
71.0	18.1	47.6	0.123	0.0329		
71.5						
72.0						
72.5				0.0388		
73.0	22.2	18.8	0.161			
73.5						
74.0				0.209		
74.5						
75.0	47.6	12.3	0.471			
75.5				0.181	0.0668	
76.0						
76.5						
77.0	72.6	0.576	0.476	0.222	0.181	
77.5						
78.0						
78.5				0.173	0.0400	
79.0	12.3	0.141	0.107			
79.5						
80.0				0.0964		
80.5						
81.0	4.61					
SIGMA						
DEG:	3.32	1.68	2.83	2.69	**	**
M:	11.5	11.6	29.6	37.5	**	**

Table A1 (contd)

NORMALIZED DOSAGES

SAND STORM NO. 29 — DATE 10 SEP 1963 — TIME 1611 PST

C/Q

[10^{-6} SEC/CU METER]

U-BAR: 7.69 METERS/SEC
DELTA T [1]: -1.2 DEG F
DELTA T [2]: -1.4 DEG F
DELTA T [3]: -2.6 DEG F

ARC NO:	3	6	7	8	9	10
DIST[M]:	200	400	600	800	1200	2400
AZIMUTH						
65.0	0.111					
65.5						
66.0						
66.5						
67.0	0.131					
67.5						
68.0						
68.5						
69.0	0.918	0.234	0.375			
69.5						
70.0						
70.5						
71.0	2.62	1.33	0.746	0.0509		
71.5						
72.0						
72.5				0.125	*0.0509	
73.0	5.33	1.23	0.654*			
73.5						
74.0				0.332	0.981	
74.5						
75.0	13.7	3.32	0.551			
75.5				1.37	2.36	
76.0						1.44
76.5						
77.0	23.6	4.25*	2.01	3.88	2.76	3.32
77.5						
78.0						3.03
78.5				5.82	3.32	
79.0	13.1*	5.48	12.3			2.14
79.5						
80.0				10.2	3.27*	1.23
80.5						
81.0	7.44	8.19	7.51			0.150
81.5				5.27	3.19	
82.0						0.124
82.5						
83.0	1.95	1.80	0.777	2.08	0.491*	
83.5						
84.0						
84.5				0.509	0.0736	
85.0	0.442*	0.124	0.0676			
85.5						
86.0				0.0572		
86.5						
87.0	0.106					
87.5						
88.0						
88.5						
89.0	0.0429					
SIGMA						
DEG:	2.96	3.27	2.61	2.14	2.43	**
M:	10.3	22.7	27.3	29.8	50.9	**

NORMALIZED DOSAGES

E/Q

[10^{-6} SEC/CU METER]

SAND STORM NO. 30
DATE 11 SEP 1963
TIME 1526 PST

U-BAR: 2.90 METERS/SEC
DELTA T [1]: -1.4 DEG F
DELTA T [2]: -1.8 DEG F
DELTA T [3]: -2.4 DEG F

ARC NO:	3	6	7	8	9	10
DIST[M]:	200	400	600	800	1200	2400
AZIMUTH						
77.0	0.0469					
77.5						
78.0						
78.5						
79.0	0.103	0.0346				
79.5						
80.0						
80.5						
81.0	0.151	0.0510				
81.5						
82.0						
82.5						
83.0	2.43	0.100				0.0655
83.5						
84.0						0.0202
84.5				0.0634		
85.0	11.6	0.0574				*0.0328
85.5						
86.0				0.107		0.0574
86.5						
87.0	26.9	0.346	0.0410			*0.0492
87.5				0.0634	*0.0492	
88.0						*0.0426
88.5						
89.0	21.3*	0.796	0.287	0.0469	0.0714	0.0387
89.5						
90.0						0.0305
90.5				0.320	0.115	
91.0	18.0	1.80	0.860			*0.0737
91.5						
92.0				0.852	0.159	0.180
92.5						
93.0	23.6	2.85	0.960			0.134
93.5				0.934	0.292	
94.0						0.195
94.5						
95.0	9.70	5.98	1.44	1.04	0.361	0.333
95.5						
96.0						0.215
96.5				1.24	0.401	
97.0	4.65	2.92	2.08			0.249
97.5						
98.0				1.52	0.346	0.500
98.5						
99.0	0.964	0.387	0.541			0.246*
99.5				1.66	0.878	
100.0						0.123
100.5						
101.0	0.152	0.136	0.459	0.860	0.819	0.361
101.5						
102.0						0.108
102.5				0.410	0.387	
103.0	0.0533	0.0429	0.136			0.0451
103.5						
104.0				0.0410	0.221	0.0778
104.5						
105.0						0.0755
105.5					*0.0410	
106.0						0.0346
SIGMA						
DEG:	3.55	3.04	3.24	3.63	3.82	5.28
M:	12.4	21.2	33.9	50.7	80.0	221.1

Table A1 (contd)

NORMALIZED DOSAGES

SAND STORM NO. 31
DATE 12 SEP 1963
TIME 1501 PST

E/Q

[10^{-6} SEC/CU METER]

U-BAR: 8.89 METERS/SEC
DELTA T [1]: -0.8 DEG F
DELTA T [2]: -1.4 DEG F
DELTA T [3]: -2.2 DEG F

ARC NO:	3	6	7	8	9	10
DIST[M]:	200	400	600	800	1200	2400
AZIMUTH						
75.0	0.0713					
75.5						
76.0						
76.5						
77.0	0.290					
77.5						
78.0						
78.5						
79.0	0.204	0.0332				
79.5						
80.0						
80.5						
81.0	4.93	0.194				
81.5				0.0373		
82.0						
82.5						
83.0	54.7	2.24	0.673	0.0664		
83.5						
84.0						
84.5				0.581	0.0664	
85.0	64.7	3.30	0.829			
85.5						
86.0				0.299	0.521	0.197
86.5						
87.0	69.0	15.4	4.99			0.627
87.5				5.21	2.80	
88.0						0.0946
88.5						
89.0	36.5	23.9	8.87	6.20	4.56	0.204
89.5						
90.0						1.02
90.5				7.13*	7.46	
91.0	26.5	25.9	11.4			2.39
91.5						
92.0				8.31	6.70	3.07
92.5						
93.0	6.64	8.26	8.46			4.79
93.5				9.32	6.27	
94.0						6.20
94.5						
95.0	1.14	4.30	4.50	6.20	4.79	3.37
95.5						
96.0						2.52
96.5				0.954	0.904	
97.0	0.380	0.239	0.400			0.591
97.5						
98.0				0.0705	0.125	0.295
98.5						
99.0	0.110	0.0498				
99.5						
100.0						
100.5						
101.0	0.0664					
SIGMA						
DEG:	2.91	2.65	2.76	2.68	2.50	2.15
M:	10.1	18.4	28.9	37.4	52.3	90.0

Table A1 (contd)

NORMALIZED DOSAGES

SAND STORM NO. 32
DATE 16 SEP 1963
TIME 1413 PST

E/Q

[10^{-6} SEC/CU METER]

U-BAR: 3.80 METERS/SEC
DELTA T [1]: -2.1 DEG F
DELTA T [2]: -2.6 DEG F
DELTA T [3]: -3.7 DEG F

ARC NO:	3	6	7	8	9	10
DIST[M]:	200	400	600	800	1200	2400
AZIMUTH						
71.0	0.228					
71.5						
72.0						
72.5						
73.0	2.36	0.0593	0.0492			
73.5						
74.0					0.125	
74.5						
75.0	27.9*	0.202	0.410*			
75.5				0.474	4.74	
76.0						
76.5						
77.0	90.8	3.67	3.33	1.33	5.41	
77.5						
78.0						0.816
78.5				4.74	6.26	
79.0	54.9	11.9	32.0			0.991
79.5						
80.0				7.37	10.6	1.27
80.5						
81.0	0.934	5.70	11.2			1.38
81.5				9.83	11.4	
82.0						4.59
82.5						
83.0	0.614	4.80	7.80	10.7	7.80	2.95*
83.5						
84.0						1.95
84.5				15.2	6.88	
85.0	0.429	7.23	8.52			1.80
85.5						
86.0				7.52	2.95*	1.44
86.5						
87.0	0.356	0.287	4.31			0.934
87.5				3.46	1.23	
88.0						0.508
88.5						
89.0	0.254		0.292	1.24	1.20	0.474
89.5						
90.0						0.243
90.5				0.444	0.787	
91.0	0.192					0.138
91.5						
92.0				0.0878	0.292	0.0655
92.5						
93.0	0.0574					0.0492
93.5					0.159	
94.0						0.0369
94.5						
95.0	0.0510				0.0410	
SIGMA						
DEG:	1.92	2.84	2.82	2.85	3.53	2.88
M:	6.6	19.7	29.5	39.8	73.8	120.4

Table A1 (contd)

NORMALIZED DOSAGES

E/Q

[10^{-6} SEC/CU METER]

SAND STORM NO. 33
DATE 8 OCT 1963
TIME 1543 PST

U-BAR: 4.51 METERS/SEC
DELTA T [1]: -0.3 DEG F
DELTA T [2]: -0.8 DEG F
DELTA T [3]: -1.5 DEG F

ARC NO:	3	6	7	8	9	10
DIST[M]:	200	400	600	800	1200	2400
AZIMUTH						
68.0					0.0663	
68.5						
69.0	1.46					
69.5					0.673	
70.0						
70.5						
71.0	2.46	0.182	0.232	0.124	1.92	
71.5						
72.0						0.0995
72.5				0.561	1.59*	
73.0	9.58	1.33	0.949			0.249
73.5						
74.0				3.08	1.37	0.663
74.5						
75.0	25.5	10.9	6.47			1.21
75.5				5.31	0.431	
76.0						1.29*
76.5						
77.0	76.0	9.12	3.95	7.00	0.124	1.38
77.5						
78.0						1.58
78.5				3.98*		
79.0	27.9	8.72	2.49			1.86
79.5						
80.0				2.29		0.786
80.5						
81.0	9.59	1.33	0.663			0.395
81.5				0.746		
82.0						*0.0829
82.5						
83.0	3.35	0.199	0.434	0.663		
SIGMA						
DEG:	2.30	2.06	2.32	2.29	1.84	2.10
M:	8.0	14.3	24.2	31.9	38.5	88.0

Table A1 (contd)

NORMALIZED DOSAGES

E/Q

[10^{-6} SEC/CU METER]

SAND STORM NO. 34
DATE 9 OCT 1963
TIME 1408 PST

U-BAR: 6.57 METERS/SEC
DELTA T [1]: -1.7 DEG F
DELTA T [2]: -1.9 DEG F
DELTA T [3]: -2.8 DEG F

ARC NO:	3	6	7	8	9	10
DIST[M]:	200	400	600	800	1200	2400
AZIMUTH						
69.0			0.0871			
69.5				0.0785		
70.0						
70.5						
71.0		0.250	0.562	0.125		
71.5						
72.0						
72.5				0.225		
73.0	0.0831	0.562	0.615			
73.5						
74.0				0.0934		
74.5						
75.0	6.48	1.90	0.475			
75.5				0.266	0.0831	
76.0						
76.5						
77.0	8.65	0.997	0.389		0.748	
77.5						
78.0						
78.5					0.326	
79.0	11.7	0.535				
79.5						
80.0						
80.5						
81.0	0.997	0.349				
81.5						
82.0						
82.5						
83.0	0.0997					
SIGMA						
DEG:	**	2.56	**	**	**	**
M:	**	17.9	**	**	**	**

Table A1 (contd)

NORMALIZED DOSAGES

E/Q

[10^{-6} SEC/CU METER]

SAND STORM NO. 35		U-BAR: 10.76	METERS/SEC
DATE 11 OCT 1963		DELTA T [1]:	-1.3 DEG F
TIME 1447 PST		DELTA T [2]:	-1.6 DEG F
		DELTA T [3]:	-2.5 DEG F

ARC NO:	3	6	7	8	9	10
DIST[M]:	200	400	600	800	1200	2400
AZIMUTH						
91.0	2.68	0.0572				
91.5						
92.0						
92.5						
93.0	11.4	0.111				
93.5						
94.0						
94.5						
95.0	25.5	0.234				
95.5						
96.0						
96.5						
97.0	40.0	0.409	0.181			
97.5						
98.0						
98.5						
99.0	63.8	3.04	0.294			
99.5						
100.0						
100.5						
101.0	38.3	22.1	0.490	0.0817	*0.0490	
101.5						
102.0						
102.5				0.245	0.0927	
103.0	18.0	27.6	2.01			
103.5						
104.0				0.508	0.164*	0.0695
104.5						
105.0	6.11	13.7	1.37			0.214
105.5				1.20	0.302	
106.0						0.291
106.5						
107.0	0.319	4.58	0.508	1.86	0.948	0.165
SIGMA						
DEG:	2.96	**	**	**	**	**
M:	10.3	**	**	**	**	**

Table A1 (contd)

NORMALIZED DOSAGES

SAND STORM NO. 36
DATE 15 OCT 1963
TIME 1608 PST

E/Q

[10^{-6} SEC/CU METER]

U-BAR: 6.65 METERS/SEC
DELTA T [1]: -0.5 DEG F
DELTA T [2]: -0.8 DEG F
DELTA T [3]: -1.6 DEG F

ARC NO:	3	6	7	8	9	10
DIST[M]:	200	400	600	800	1200	2400
AZIMUTH						
77.0	0.0823					
77.5						
78.0						
78.5						
79.0	1.96					
79.5						
80.0						
80.5						
81.0	6.85	0.247	0.0412			
81.5						
82.0						
82.5						
83.0	13.8	4.46	1.88	0.202		0.138
83.5						
84.0						0.390
84.5				2.78	0.145	
85.0	44.6	9.38	6.37			0.698
85.5						
86.0				3.34	3.05	0.769
86.5						
87.0	84.0	12.3	6.58			0.988
87.5				4.89	3.34	
88.0						1.38
88.5						
89.0	62.9	26.3	7.84	5.10	4.33	1.96
89.5						
90.0						1.30
90.5				6.16	4.61	
91.0	9.81	5.76*	8.25			0.0576
91.5						
92.0				1.21	1.23	0.105
92.5						
93.0	4.18	1.22	1.96			0.0329
93.5				0.0905	0.0708	
94.0						
94.5						
95.0	0.658	0.0947	0.0412			
95.5						
96.0						
96.5						
97.0	0.202					
SIGMA						
DEG:	2.48	2.35	2.72	2 23	1.91	1.96
M:	8.6	16.4	28.5	31.0	40.1	81.9

Table A1 (contd)

SAND STORM NO. 37	NORMALIZED DOSAGES	U-BAR: 6.40 METERS/SEC
DATE 22 OCT 1963	E/Q	DELTA T [1]: -0.4 DEG F
TIME 1534 PST	[10^{-6} SEC/CU METER]	DELTA T [2]: -0.6 DEG F
		DELTA T [3]: -1.1 DEG F

ARC NO:	3	6	7	8	9	10
DIST[M]:	200	400	600	800	1200	2400
AZIMUTH						
65.0	0.0406					
65.5						
66.0						
66.5						
67.0	0.593					
67.5						
68.0						
68.5						
69.0	4.70					
69.5						
70.0						
70.5						
71.0	14.3	0.390*	0.483	0.101		
71.5						
72.0						0.0383
72.5				0.801	0.226	
73.0	12.2	6.21	3.30			
73.5						
74.0				2.34	0.461	
74.5						
75.0	4.06	4.96	2.66			
75.5				1.14	0.608	
76.0						
76.5						
77.0	3.30	3.17	1.28	0.926	0.0790	
77.5						
78.0						
78.5				0.171		
79.0	1.36	0.343	0.634			
79.5						
80.0						
80.5						
81.0	0.232	0.0333	0.0343			
81.5						
82.0						
82.5						
83.0	0.0426					
SIGMA						
DEG:	2.64	1.80	**	1.67	**	**
M:	9.2	12.5	**	23.3	**	**

Table A1 (contd)

NORMALIZED DOSAGES

SAND STORM NO. 38
DATE 23 OCT 1963
TIME 1335 PST

E/Q

[10^{-6} SEC/CU METER]

U-BAR: 9.26 METERS/SEC
DELTA T [1]: -1.4 DEG F
DELTA T [2]: -1.7 DEG F
DELTA T [3]: -2.6 DEG F

ARC NO:	3	6	7	8	9	10
DIST[M]:	200	400	600	800	1200	2400
AZIMUTH						
67.0	0.0388					
67.5						
68.0						
68.5						
69.0	0.0558					
69.5						
70.0						
70.5						
71.0	0.196	0.0439				
71.5						
72.0						
72.5						
73.0	2.70	0.0782	0.0782			
73.5						
74.0				0.0319		
74.5						
75.0	7.45	0.456	0.128			0.0518
75.5				0.0550	0.0448	
76.0						0.0917
76.5						
77.0	28.4	1.34	1.03	0.196	1.28	0.156
77.5						
78.0						0.187
78.5				2.03	1.61	
79.0	48.7	5.82	5.01			0.257
79.5						
80.0				5.82	4.05	0.877
80.5						
81.0	67.6	28.4	11.3			0.696
81.5				8.63	4.53	
82.0						1.12
82.5						
83.0	47.4	31.1	21.5	10.7	6.64	2.84
83.5						
84.0						1.75
84.5				9.65	6.51	
85.0	25.5	30.3	16.0*			2.84
85.5						
86.0				10.5	4.26	1.34
86.5						
87.0	14.0	9.25	14.0			1.12
87.5				7.32	4.39	
88.0						1.05
88.5						
89.0	5.97	4.47	5.26	6.45	4.87	1.05
89.5						
90.0						0.317
90.5				3.78	1.05	
91.0	4.95	0.337	0.555			0.124
91.5						
92.0				0.555	0.772	
92.5						
93.0	0.597		0.134			
93.5				0.0909	0.190	
SIGMA						
DEG:	3.53	2.59	2.91	3.29	3.58	2.92
M:	12.3	18.0	30.4	45.8	74.9	122.3

Table A1 (contd)

NORMALIZED DOSAGES

E/Q

[10^-6 SEC/CU METER]

SAND STORM NO. 40
DATE 30 OCT 1963
TIME 1131 PST

U-BAR: 6.83 METERS/SEC
DELTA T [1]: -1.8 DEG F
DELTA T [2]: -2.7 DEG F
DELTA T [3]: -3.0 DEG F

ARC NO:	3	6	7	8	9	10
DIST[M]:	200	400	600	800	1200	2400
AZIMUTH						
65.0	0.668	0.248				
65.5						
66.0						
66.5						
67.0	2.37	1.03	0.180			
67.5						
68.0				0.278		
68.5						
69.0	20.8	2.52	0.618			
69.5				0.970	0.198	
70.0						
70.5						
71.0	41.7	9.42	3.23	2.26	2.01	
71.5						
72.0						
72.5				2.75	1.33	
73.0	52.0	10.9	8.55			
73.5						
74.0				3.48		
74.5						
75.0	31.7	14.0	2.74			
75.5						
76.0						
76.5						
77.0	25.2*	2.70				
77.5						
78.0						
78.5						
79.0	20.4					
79.5						
80.0						
80.5						
81.0	5.51					
81.5						
82.0						
82.5						
83.0	1.40					
83.5						
84.0						
84.5						
85.0	0.242					
SIGMA						
DEG:	3.39	2.38	**	**	**	**
M:	11.8	16.6	**	**	**	**

Table A1 (contd)

SAND STORM NO. 41	NORMALIZED DOSAGES	U-BAR: 8.96 METERS/SEC
DATE 4 NOV 1963	C/Q	DELTA T [1]: -1.8 DEG F
TIME 1208 PST		DELTA T [2]: -2.0 DEG F
	[10^{-6} SEC/CU METER]	DELTA T [3]: -3.1 DEG F

ARC NO:	3	6	7	8	9	10
DIST[M]:	200	400	600	800	1200	2400
AZIMUTH						
59.0	0.181	0.0821	0.304	0.361	0.166	
59.5						
60.0						
60.5				0.594	0.640	
61.0	0.474	1.17	1.09			
61.5						
62.0				2.28	0.697	0.0944
62.5						
63.0	3.12	3.33	2.36			0.181
63.5				3.76	1.53	
64.0						0.208
64.5						
65.0	5.71	5.91	5.84	4.17	2.08	0.333
65.5						
66.0						0.781
66.5				4.74	3.46	
67.0	18.1	18.1	7.94			1.02
67.5						
68.0				7.30	4.10	0.757
68.5						
69.0	46.0	20.8	10.5			0.389
69.5				9.29	5.01	
70.0						0.208
70.5						
71.0	55.8	17.2	11.5	7.60	2.56	0.130
71.5						
72.0						0.0903
72.5				7.81	1.27	
73.0	36.1	24.9	14.4			0.0369
73.5						
74.0				2.92	0.430	
74.5						
75.0	23.6	27.7	4.66			
75.5				1.38	0.0903	
76.0						
76.5						
77.0	43.2	17.2	3.33	1.44	0.222	
77.5						
78.0						
78.5				2.08	0.128	
79.0	19.5	7.30	2.92			
79.5						
80.0				1.08		
80.5						
81.0	6.33	1.08	0.0410			
81.5				0.0328		
82.0						
82.5						
83.0	0.648					
83.5						
84.0						
84.5						
85.0	0.0356					
SIGMA						
DEG:	4.09	4.18	4.15	4.33	3.32	2.21
M:	14.2	29.1	43.4	60.5	69.6	92.5

Table A1 (contd)

NORMALIZED DOSAGES

E/Q

[10^{-6}SEC/CU METER]

SAND STORM NO. 42
DATE 5 NOV 1963
TIME 1425 PST

U-BAR: 10.18 METERS/SEC
DELTA T [1]: -1.3 DEG F
DELTA T [2]: -1.5 DEG F
DELTA T [3]: -2.4 DEG F

ARC NO:	3	6	7	8	9	10
DIST[M]:	200	400	600	800	1200	2400
AZIMUTH						
57.0	0.0416					
57.5						
58.0						
58.5						
59.0	0.0457					
59.5						
60.0						
60.5						
61.0	0.366					
61.5						
62.0				*0.0832	0.0665	
62.5						
63.0	0.665	0.0707	0.0644			0.101
63.5				0.273	0.183	
64.0						0.211
64.5						
65.0	1.98	0.216	0.665	0.665	0.253	0.198
65.5						
66.0						0.225
66.5				0.873	0.536	
67.0	7.7[illegible]	3.24	2.66			0.0915
67.5						
68.0				1.16	1.16	0.0205
68.5						
69.0	24.0	5.99	4.16*			0.110
69.5				2.96	0.948	
70.0						*0.0965
70.5						
71.0	42.3	7.05	6.22	4.08		0.0832
71.5						
72.0						
72.5				2.05		
73.0	25.3	8.12	12.7			
73.5						
74.0				0.183		
74.5						
75.0	19.8	4.01	1.38			
75.5						
76.0						
76.5						
77.0	1.75	0.374	0.0499			
77.5						
78.0						
78.5						
79.0	0.0333					
SIGMA						
DEG:	2.64	2.62	2.40	2.41	1.90	**
M:	9.2	18.2	25.1	33.6	39.7	**

Table A1 (contd)

SAND STORM NO. 43	NORMALIZED DOSAGES	U-BAR: 7.34 METERS/SEC
DATE 7 NOV 1963	E/Q	DELTA T [1]: -1.2 DEG F
TIME 1422 PST		DELTA T [2]: -1.6 DEG F
	[10^{-6} SEC/CU METER]	DELTA T [3]: -2.2 DEG F

ARC NO:	3	6	7	8	9	10
DIST[M]:	200	400	600	800	1200	2400
AZIMUTH						
65.0	0.264					
65.5						
66.0						
66.5						
67.0	1.27					
67.5						
68.0						
68.5						
69.0	2.02	0.894	0.202			
69.5				0.0410		
70.0						0.0677
70.5						
71.0	9.64	1.41	0.0902	0.100	0.0451	0.101
71.5						
72.0						0.221
72.5				0.246	0.246	
73.0	9.35	0.866	0.640			0.123
73.5						
74.0				0.820	0.287	
74.5						
75.0	15.3	2.92	0.894			
75.5				2.21	1.80	
76.0						
76.5						
77.0	11.9	2.36	0.553	1.23	1.08	
77.5						
78.0						
78.5				0.877		
79.0	4.02	1.53	0.738			
79.5						
80.0				0.208		
80.5						
81.0	0.202	0.109	0.0510			
81.5				0.0553		
SIGMA						
DEG:	2.93	3.08	**	2.02	**	**
M:	10.2	21.5	**	28.1	**	**

Table A1 (contd)

NORMALIZED DOSAGES

E/Q

[10^{-6} SEC/CU METER]

SAND STORM NO. 44
DATE 13 NOV 1963
TIME 1408 PST

U-BAR: 4.48 METERS/SEC
DELTA T [1]: -1.0 DEG F
DELTA T [2]: -1.3 DEG F
DELTA T [3]: -1.9 DEG F

ARC NO:	3	6	7	8	9	10
DIST[M]:	200	400	600	800	1200	2400
AZIMUTH						
54.5				0.410		
55.0	0.0363	0.0847	0.115			
55.5						
56.0				0.389		
56.5						
57.0	1.92	0.462	0.363			
57.5				0.169	*0.0404	
58.0						
58.5						
59.0	8.09	0.0404	0.220	0.0865	0.0888	
59.5						
60.0						
60.5				0.0404	0.0565	
61.0	2.45	0.0161	0.242			
61.5						
62.0				0.0494	0.0381	
62.5						
63.0	0.936	0.199	0.0775			
63.5				0.0544	*0.0387	
64.0						0.0605
64.5						
65.0	0.520	0.218	0.0815		0.0404	0.0565
65.5						
66.0						
66.5					*0.0533	
67.0	0.444	0.0686	0.0605			
67.5						
68.0					0.0704	
68.5						
69.0	0.0625	0.0784	0.0161			
69.5						
70.0						
70.5						
71.0			0.0350			
SIGMA						
DEG:	2.30	**	**	**	**	**
M:	8.0	**	**	**	**	**

Table A2. Remarks Concerning Table A1

Run	Position	Remarks
2	3-53	Interpolated; dead engine, gas 2/3 full.
3	5-65	Interpolated; dead engine, gas full.
	5-77	Estimated; 1/2 filter missing.
	9-73	Interpolated; dead engine, gas full, cock closed.
	9-75	Interpolated; dead engine, gas full, cock closed.
	9-81	Interpolated; dead engine, gas full, cock closed.
	9-83	Interpolated; dead engine, gas full, cock closed.
	10-77	Interpolated; sample lost.
	10-78	Interpolated; filter torn.
5	2-53	Interpolated; dead engine, gas 3/4 full.
	7-53	Interpolated; dead engine, gas 2/3 full.
	7-71	Interpolated; sample lost.
	9-65	Interpolated; sample lost.
	9-67	Interpolated; sample lost.
	9-77	Interpolated; sample spilled.
	10-62	Interpolated; filter damaged.
	10-75	Interpolated; sample lost.
	10-76	Interpolated; sample lost.
6	5-83	Interpolated; filter lost.
7	1-57	Interpolated; extremely low assay, no explanation.
	5-59	Interpolated; filter lost.
11	4-53	Interpolated; filter lost.
	6-68	Interpolated; filter damaged.
	9-55	Interpolated; engine dead, gas full, cock closed.
	10-71	Interpolated; filter lost.
12	1-57	Interpolated; engine dead, gas 3/4 full.
	7-77	Interpolated; engine dead, gas full.
14	7-89	Interpolated; dead engine, gas full, cock closed.
	10-90	Interpolated; dead engine, gas full, cock closed.
16	3-85	Interpolated; dead engine, gas 3/4 full.
	6-99	Interpolated; dead engine, gas 3/4 full, engine seized.
	6-103	Interpolated; dead engine, gas 3/4 full, engine seized.
	8-96.5	Interpolated; dead engine, gas full, cock closed.
	9-102.5	Interpolated; dead engine, gas 3/4 full, engine seized.
	10-90	Interpolated; no sample collected.

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Table A2 (contd)

Run	Position	Remarks
17	9-81.5	Interpolated; low vacuum.
18	3-67	Interpolated; engine dead, gas full.
	6-63	Interpolated; engine dead, gas 3/9, engine seized.
	6-69	Interpolated; low vacuum.
	6-73	Interpolated; orifice plugged.
	9.57.5	Interpolated; engine dead, fuel cap off.
	9-59	Interpolated; engine dead, fuel cap off.
20	3-67	Interpolated; dead engine, gas 1/2 full.
	8-86	Interpolated; filter torn.
	9-78.5	Interpolated, dead engine, gas 1/2 full.
	9-83	Interpolated; sample spilled.
	9-89	Interpolated, low vacuum.
	10-61	Interpolated, filter lost.
	10-64	Interpolated, dead engine, gas 3/4 full.
21	3-85	Interpolated; dead engine, gas 3/4 full, engine seized.
	6-71	Interpolated; dead engine, fuel cap off.
	6-83	Interpolated; dead engine, fuel cap off.
	8-71	Interpolated; dead engine, gas full.
	8-75.5	Interpolated; sample spilled.
	9-74	Interpolated; low vacuum.
	9-86	Interpolated; dead engine, gas full.
	10-73	Interpolated; dead engine, gas 3/4 full.
	10-81	Interpolated; filter torn.
	10-84	Interpolated; dead engine, gas 3/4 full.
22	3-95	Interpolated; dead engine, gas full.
	6-93	Interpolated; dead engine, gas 1/2 full.
	6-103	Interpolated; filter lost.
24	3-91	Interpolated; dead engine, gas 3/4 full.
	8-81.5	Interpolated; dead engine, gas 3/4 full.
	10-87	Interpolated; damaged filter.
25	3-69	Interpolated; low vacuum.
	8-78.5	Interpolated; damaged filter.
26	8-62	Interpolated; damaged filter.
	9-75.5	Interpolated; lost filter.
	9-60.5	Interpolated; sample spilled.

Table A2 (contd)

Run	Position	Remarks
26	9-65	Interpolated; dead engine, gas full.
	10-64	Interpolated; filter lost.
	10-69	Interpolated; dead engine, gas 3/4 full, seized engine.
27	7-65.0	Interpolated; damaged filter.
	8-65.0	Interpolated; damaged filter.
	9-57.5	Interpolated; dead engine, gas 3/4 full.
	10-59	Interpolated; filter lost.
	10-62	Interpolated; low vacuum.
28	3-67	Interpolated; dead engine, gas 1/2 full.
29	3-79	Interpolated; damaged filter.
	3-85	Interpolated; dead engine, gas 3/4 full.
	6-77	Interpolated; dead engine, gas full.
	7-73	Interpolated; damaged filter.
	9-72.5	Interpolated; spilled sample.
	9-80	Interpolated; dead engine, gas 3/4 full.
	9-83	Interpolated; dead engine, gas 3/4 full.
30	3-89	Interpolated; dead engine, gas full.
	9-87.5	Interpolated; dead engine, gas 1/2 full.
	9-105.5	Interpolated; dead engine, gas 1/2 full.
	10-85	Interpolated; damaged filter.
	10-87	Interpolated; damaged filter.
	10-88	Interpolated; damaged filter.
	10-91	Interpolated; dead engine, gas full.
	10-99	Interpolated; dead engine, gas 1/2 full.
31	8-90.5	Interpolated; dead engine, gas full.
32	3-75	Interpolated; dead engine, gas 3/4 full.
	7-75	Interpolated; dead engine, gas 3/4 full.
	9-86	Interpolated; dead engine.
	10-83	Interpolated; lost filter.
33	8-78.5	Interpolated; damaged filter.
	9-72.5	Interpolated; damaged filter.
	10-76	Interpolated; spilled sample.
	10-82	Interpolated; damaged filter.
35	9-101	Interpolated; damaged filter.
	9-104	Interpolated; damaged filter.

Table A2 (c ›ntd)

Run	Position	Remarks
36	6-91	Interpolated; dead engine, fuel line off.
37	6-71	Interpolated; damaged filter.
38	7-85	Interpolated; spilled sample.
40	3-77	Interpolated; dead engine, gas 3/4 full.
42	7-69	Interpolated; lost filter.
	8-62	Interpolated; dead engine, gas 3/4 full.
	10-70	Interpolated; dead engine, gas 3/4 full.
44	9-57.5	Interpolated; lost filter.
	9-63.5	Interpolated; damaged filter.
	9-66.5	Interpolated; dead engine, gas 3/4 full.

Table A3. Source Data

Experiment Number	Date (1963)	Weight of Expended Propellant (pounds)	Firing Duration (seconds)
2	27 March	7.20	5.4
3	8 April	25.00	5.0
4	19 April	Unknown	Unknown
5	24 April	7.60	5.1
6	6 May	15.04	3.9
7	8 May	15.05	8.0
8	22 May	14.90	4.9
9	23 May	14.77	5.0
10	29 May	25.74	2.5
11	10 June	25.95	2.4
12	12 June	25.95	2.5
13	14 June	24.90	8.0
14	19 June	15.00	4.7
16	9 July	23.07	6.3
17	11 July	22.54	7.5
18	15 July	14.51	4.2
19	17 July	13.96	5.3
20	26 July	30.43	7.8
21	30 July	30.52	8.1
22	9 August	30.85	8.5
23	16 August	30.69	7.7
24	19 August	29.97	7.7
25	21 August	65.81	7.1
26	22 August	66.53	7.2
27	27 August	65.56	7.1
28	30 August	65.47	7.1
29	10 September	65.88	7.3
30	11 September	65.75	7.2
31	12 September	64.95	7.8
32	16 September	65.75	7.3
33	8 October	39.71	5.3
34	9 October	39.60	5.9
35	11 October	65.92	7.6
36	15 October	65.45	7.3
37	22 October	66.31	7.9
38	23 October	67.53	7.5
39	29 October	22.54	8.2
40	30 October	15.00	5.0
41	4 November	65.66	6.8
42	5 November	64.78	7.0
43	7 November	65.68	8.1
44	13 November	66.75	7.7

Appendix B

Phototheodolite Data

The data presented in this appendix were taken from three phototheodolite cameras, Model KTH 53. The cameras were pulsed simultaneously at a rate of four frames per second and recorded the azimuth and elevation of the aiming point as well as the time. One camera was positioned approximately one-third mile upwind of the firing pad. The other two were positioned approximately one mile from the firing pad on a line normal to the centerline of the sampling grid. Camera locations relative to the firing pad and sampling grid are shown in Figure 6 of Chapter III in the report. Triangulation with the camera closest to the firing pad and either of the other two cameras sufficed to fix the position in space and time of any portion of the cloud observed by the two cameras.

For many of the experiments it was possible to identify only the top of the cloud from two camera positions simultaneously. Consequently the height, rate of rise, and the rate of transport of the top of the cloud was the only information obtained from those experiments. For others it was possible to determine the crosswind dimension from the angular width taken from pictures made by the upwind camera. For a few experiments the dimension in the direction of travel was determined from the angular spread of the cloud in pictures made by one or both of the other two cameras. It was never possible, however, to identify both the top and the base of the visible cloud simultaneously, so that estimates of the height of the cloud's center were not possible; hence, we were unable to determine the effective source height with reasonable accuracy.

Adverse weather conditions, such as blowing sand which could damage camera lenses and haze which made cloud definition poor, as well as priority commitments of camera crews, reduced the number of diffusion experiments supported by phototheodolite measurements to 32. Of these, some were of less than 20 seconds duration.

The tabulations which follow present the position of the cloud top and the cloud width and length as a function of time after the cloud was first observed by one of the cameras. This time can be taken to be about 1 to 2 seconds after ignition. The X coordinate is oriented along the centerline of the 90-degree sampling grid, that is, the 062-degree true azimuth from the firing pad. The Y coordinate is normal to the X coordinate, with positive values to the south and negative values to the north.

Table B1. Phototheodolite Data

SAND STORM NO. 2

DATE: 27 Mar 63

TIME	POSITION OF TOP			WIDTH	LENGTH
	Z	Y	X		
(seconds)	(feet)	(feet)	(feet)	(feet)	(feet)
3	15.9	- 6.5	146.1		
4	18.2	- 5.2	179.3		
5	21.5	- 6.8	214.4		
6	23.0	-10.1	251.1		
7	25.5	- 9.1	288.3		
8	22.5	-17.9	316.8		
9	23.6	-24.5	350.3		
10	25.3	-13.8	401.3		
11	25.5	-17.9	433.6		
12	27.4	-28.0	462.6		
13	26.5	-32.9	510.8		
14	29.5	-38.6	537.7		
15	29.9	-41.4	562.9		
16	35.3	-56.8	580.7		

SAND STORM NO. 3

DATE: 8 Apr 63

TIME	POSITION OF TOP			WIDTH	LENGTH
	Z	Y	X		
(seconds)	(feet)	(feet)	(feet)	(feet)	(feet)
2	18.5	17.0	99.2	13.8	
3	23.2	26.1	133.4	26.6	
4	24.8	28.9	150.9	31.8	
5	29.2	32.8	183.3	35.9	
6	34.9	42.0	214.4	45.4	
7	39.0	44.6	244.9	51.9	
8	43.8	46.2	272.8	61.1	
9	49.8	58.0	299.7	68.0	
10	53.6	57.2	338.2	71.8	
11	63.8	65.0	360.8	75.7	
12	73.5	71.7	396.5	79.4	
13	83.2	77.8	427.3	77.4	
14	95.4	86.2	463.4	85.3	
15	103.1	85.2	496.7	96.6	
16	110.8	96.6	534.6	104.0	
17	118.4	106.1	564.1		
18	133.8	[illegible].5	606.3		
19	139.5	121.2	651.0	106.5	
20	152.3	135.3	691.6	106.3	
24	177.6	180.1	848.3	134.6	

Table B1 (contd)

SAND STORM NO. 4

DATE: 19 Apr 63

TIME	POSITION OF TOP			WIDTH	LENGTH
	Z	Y	X		
(seconds)	(feet)	(feet)	(feet)	(feet)	(faet)
2	23.3	1.2	106.1		
3	29.6	13.0	151.8		
4	41.4	5.6	196.3		
5	48.8	5.6	[illegible]		
6	54.8	4.2	286.9		
7	61.0	5.3	331.[illegible]		
8	71.4	.2	374.1		
9	73.7	13.8	420.9		
10	80.0	11.7	465.1		
11	86.9	15.8	510.1		
12	95.3	23.5	554.9		

Table B1 (contd)

SAND STORM NO. 6

DATE: 6 May 63

TIME (seconds)	POSITION OF TOP Z (feet)	POSITION OF TOP Y (feet)	POSITION OF TOP X (feet)	WIDTH (feet)	LENGTH (feet)
0	4.9	2.2	14.8	4.8	
1	16.1	20.3	74.4	31.0	
2	31.9	35.3	110.3	38.3	
3	39.4	44.6	128.5	55.0	
4	46.9	52.4	146.8	59.7	
5	52.2	61.0	171.3	67.2	
6	51.5	69.5	194.0	72.4	
7	59.2	76.8	214.7	76.4	
8	54.9	85.5	242.0	77.7	
9	56.6	99.9	283.5	85.8	
10	61.5	99.8	301.3	87.0	
11	64.0	106.1	326.2	92.4	
12	73.4	113.0	351.4	89.5	
13	84.8	128.0	374.3	89.1	
14	89.0	129.9	400.4	93.4	
15	97.1	134.3	427.5	90.7	
16	102.4	135.0	453.4	94.9	
17	108.9	140.7	477.0	96.8	
18	112.0	148.9	498.7	99.5	
19	108.5	155.5	526.7	101.9	
20	115.8	164.6	551.6	106.4	
25	144.9	196.4	686.0	113.5	
30	153.3	215.3	788.9		
31	164.3	231.9	[illegible].1		

Table B1 (contd)

SAND STORM NO.7

DATE: 8 May 63

TIME (seconds)	POSITION OF TOP Z (feet)	Y (feet)	X (feet)	WIDTH (feet)	LENGTH (feet)
0	10.6	6.5	43.2		
1	19.7	12.7	85.7		
2	28.1	25.7	131.4		
3	40.3	23.4	165.4		
4	46.2	18.5	179.7		
5	52.3	19.4	219.2		
6	58.4	15.9	242.9		
7	64.8	16.8	271.6		
8	73.7	18.0	294.6		
9	77.5	15.9	341.4		
10	80.3	7.2	374.6		

Table B1 (contd)

SAND STORM NO. 1C

DATE: 27 May 63

TIME (seconds)	POSITION OF TOP Z (feet)	Y (feet)	X (feet)	WIDTH (feet)	LENGTH (feet)
0	17.2	8.9	77.7		
1	30.1	28.2	106.9		
2	31.8	31.9	127.8		
3	33.8	46.0	164.6		
4	44.5	48.9	174.2		
5	52.0	66.3	225.6		
6	62.1	75.2	234.7		
7	71.6	76.1	246.3		
8	75.7	77.1	251.3		
9	78.0	75.8	249.7		
10	89.8	80.9	268.3		
11	92.2	82.9	276.0		
12	95.0	84.2	288.7		
13	98.2	90.3	303.5		
14	101.0	91.4	306.9		
15	110.2	92.5	319.1		
16	117.5	94.0	326.0		
17	120.1	100.1	337.5		
18	123.8	103.3	351.9		
19	131.1	105.9	358.9		
20	138.8	103.4	374.1		
25	175.0	106.3	447.1		
30	210.4	98.8	531.8		
35	244.9	105.7	608.2		
36	252.8	109.1	624.1		

Table B1 (contd)

SAND STORM NO. 13

DATE: 14 June 63

TIME (seconds)	POSITION OF TOP Z (feet)	POSITION OF TOP Y (feet)	POSITION OF TOP X (feet)	WIDTH (feet)	LENGTH (feet)
0	8.2	2.1	20.7		
1	18.2	10.0	65.0		
2	24.9	14.7	86.3	44.0	
3	27.9	21.4	126.0	51.4	
4	38.7	24.8	142.9	60.1	
5	49.3	21.2	151.2		
6	55.7	21.2	159.6	66.4	
7	60.1	19.8	170.3	68.3	
8	64.5	18.9	176.0		
9	69.8	20.7	186.7		
10	74.0	29.0	217.8		
11	83.5	26.8	221.7	80.8	
12	91.8	24.9	225.7		
13	96.3	19.5	231.6	82.3	
14	104.8	18.6	237.4		
15	114.1	18.5	246.0	88.7	
16	119.5	19.9	250.6		
17	128.4	21.7	259.5		
18	136.4	23.4	261.2		
19	139.7	27.2	271.2		
25	162.4	70.0	374.0		
30	196.1	91.1	417.9		
35	225.4	110.5	463.5		
40	240.9	147.8	491.3		

Table B1 (contd)

SAND STORM NO. 14

DATE: 19 June 63

TIME (seconds)	POSITION OF TOP Z (feet)	Y (feet)	X (feet)	WIDTH (feet)	LENGTH (feet)
0	12.0	9.9	38.6		
1	19.1	28.7	76.5	36.5	
2	18.8	37.6	91.6	47.0	
3	19.8	50.9	137.3	61.2	
4	28.4	63.7	166.1	65.9	
5	31.7	60.6	181.4		
6	39.4	67.4	194.4	67.3	
7	43.1	66.0	204.7	68.3	
8	44.9	76.1	225.8	68.9	
9	50.2	84.9	243.0		
10	55.6	92.8	254.5	69.6	
11	57.7	93.7	261.6		
12	59.7	107.0	282.4	72.8	
13	65.7	106.8	300.9	74.4	
14	67.5	118.2	310.5		
15	70.0	122.5	318.2		
16	81.5	116.9	332.8	78.5	
17	83.0	129.2	346.0	76.9	
18	87.4	133.0	357.1	81.0	
19	89.4	132.1	372.8		
20	93.7	143.1	391.2		
25	112.5	173.0	456.6		

Table B1 (contd)

SAND STORM NO. 16

DATE: 9 July 63

TIME (seconds)	POSITION OF TOP Z (feet)	Y (feet)	X (feet)	WIDTH (feet)	LENGTH (feet)
0	3.8	3.8	16.8		
1	18.6	25.4	81.3		
2	25.4	23.7	107.6		
3	30.5	33.1	119.5		
4	33.3	42.5	131.1		
5	34.1	45.8	135.6		
6	36.5	56.5	168.4		
7	43.6	60.7	188.0		
8	47.6	62.1	192.2		
9	49.1	67.0	203.0		
10	55.8	72.8	215.8		
11	59.3	83.7	234.5		
12	66.4	8[illegible].7	250.3		
13	70.0	87.7	267.6		
14	69.7	96.0	278.4		
15	76.4	100.4	304.9		
16	81.7	104.2	313.7		
17	88.8	110.2	328.1		
18	88.7	119.4	335.0		

SAND STORM NO. 17

DATE: 11 July 63

TIME (seconds)	POSITION OF TOP Z (feet)	Y (feet)	X (feet)	WIDTH (feet)	LENGTH (feet)
0	7.1	1.1	.3	6.7	
1	12.8	6.0	26.9	21.8	
2	23.1	24.9	72.9	41.5	
3	32.0	30.6	108.7	51.4	
4	35.4	32.4	129.4	62.5	
5	39.2	39.5	154.2	71.9	
6	41.7	34.5	169.0	78.1	
7	47.1	39.3	177.0	83.9	
8	48.1	47.3	188.6		
9	53.0	54.5	218.4	91.2	
10	58.2	61.1	229.7	91.5	
11	65.8	66.9	248.6	91.9	
12	68.4	74.0	259.4	92.4	

Table B1 (contd)

SAND STORM NO. 18

DATE: 15 July 63

TIME (seconds)	POSITION OF TOP Z (feet)	Y (feet)	X (feet)	WIDTH (feet)	LENGTH (feet)
1	18.8	11.3	65.6		
2	19.9	8.8	106.2		
3	26.0	8.5	138.5		
4	29.9	11.2	166.4		
5	35.4	9.3	194.4		
6	40.0	6.1	223.0		
7	45.2	8.9	250.9		
8	49.2	6.9	276.0		
9	53.0	9.9	295.9		
10	57.4	7.2	318.1		
11	63.6	21.0	339.8		
12	71.2	22.3	366.2		
13	78.6	25.3	388.5		
14	83.6	23.4	413.2		
15	87.9	24.5	447.0		
16	93.0	25.1	467.7		
17	98.9	20.0	496.5		
18	103.8	18.5	522.4		
19	109.2	18.2	547.2		
20	112.6	18.6	573.0		
25	127.6	14.3	691.4		
30	142.7	9.1	822.7		
34	153.5	- 7.7	887.3		

Table B1 (contd)

SAND STORM NO. 19

DATE: 17 July 63

TIME (seconds)	POSITION OF TOP Z (feet)	Y (feet)	X (feet)	WIDTH (feet)	LENGTH (feet)
0	6.8	6.6	17.7		
1	14.1	22.[illegible]	71.5	29.8	
2	20.6	31.2	108.7	41.1	
3	25.5	4[illegible].0	147.7	51.5	
4	23.9	41.5	154.0	56.1	
5	26.5	48.5	170.3	60.3	
6	28.1	57.9	196.6	67.7	
7	30.6	64.5	216.8	68.0	
8	39.4	80.8	263.6	74.5	
9	45.1	91.3	287.0	79.2	
10	45.9	101.5	311.4		
11	54.2	120.0	335.7	92.1	
12	62.9	135.3	354.2		
13	74.1	151.4	398.3	98.2	
14	78.2	157.9	419.6		
15	88.9	169.2	460.3		
16	92.7	179.1	494.4	109.0	

Table B1 (contd)

SAND STORM NO. 20

DATE: 26 July 63

TIME	POSITION OF TOP			WIDTH	LENGTH
	Z	Y	X		
(seconds)	(feet)	(feet)	(feet)	(feet)	(feet)
0	13.1	11.5	55.2		
1	21.0	21.5	95.9		
2	25.8	27.7	126.2		
3	29.7	32.3	150.1		
4	33.5	36.2	178.0		
5	38.7	39.1	199.3		
6	45.7	47.9	225.3		
7	54.7	49.3	244.4		
8	64.0	54.1	264.5		
9	72.6	56.3	278.8		
10	80.0	54.6	291.1		
11	87.0	57.5	307.9		
12	92.6	62.3	322.6		
13	97.9	67.7	338.3		
14	103.9	71.1	352.6		
15	108.1	74.8	368.5		
16	113.7	77.8	385.4		
17	116.9	75.8	400.8		
18	123.5	74.9	410.2		
19	131.5	82.0	433.9		
20	135.9	83.7	449.9		
25	169.0	98.2	519.3		
30	199.4	120.5	587.6		
35	233.0	142.4	676.6		
40	268.5	175.8	722.3		
45	297.5	238.7	783.6		
48	307.5	263.3	797.8		

Table B1 (contd)

SAND STORM NO. 21

DATE: 30 July 63

TIME	POSITION OF TOP			WIDTH	LENGTH
	Z	Y	X		
(seconds)	(feet)	(feet)	(feet)	(feet)	(feet)
0	4.2	2.0	22.3	5.9	
1	19.2	16.6	81.5	44.9	
2	24.5	12.4	124.8	57.0	
3	28.6	20.5	176.6	65.4	
4	34.9	69.1	206.6	65.9	
5	40.2	83.4	237.3	69.9	
6	45.8	91.5	273.1	76.5	
7	51.8	100.8	307.1	80.3	
8	57.3	111.5	340.1	86.7	
9	61.4	122.8	383.9	94.4	
10	63.5	129.9	402.7		
11	70.3	137.6	435.7		
12	74.3	149.8	465.9		
13	82.0	157.1	501.2		
14	87.3	171.4	531.7		
15	93.6	180.0	562.5		
16	98.3	187.5	584.7		
17	104.6	198.0	621.4		
18	110.1	201.1	654.4		
19	114.7	209.0	684.4		
20	120.0	216.3	715.5		
25	137.7	240.8	850.5		
30	159.5	284.8	1010.1		
35	190.9	319.8	1157.7		
40	208.1	330.5	1299.4		
45	222.2	387.2	1453.5		
48	231.0	367.4	1530.7		

Table B1 (contd)

SAND STORM NO. 22

DATE: 9 Aug 63

TIME	POSITION OF TOP			WIDTH	LENGTH
	Z	Y	X		
(seconds)	(feet)	(feet)	(feet)	(feet)	(feet)
0	4.9	4.0	19.2		
1	18.9	24.3	66.2		
2	21.8	37.6	100.1		
3	20.4	42.8	130.7		
4	28.2	63.2	150.2		
5	33.0	75.3	168.7		
6	35.6	85.9	185.0		
7	44.2	93.3	200.9		
8	48.3	103.0	217.5		
9	55.4	104.8	240.5		
10	62.6	117.4	261.5		
11	68.0	127.7	275.2		
12	70.6	135.9	284.1		
13	74.5	136.9	298.7		
14	80.4	142.9	308.0		
15	87.0	150.1	315.0		
16	92.5	155.8	326.1		
17	99.5	162.6	340.5		
18	104.8	173.9	351.6		
19	109.0	182.7	362.7		
20	116.5	194.0	386.5		
25	117.4	250.7	457.5		
30	133.8	307.8	522.0		
35	145.6	353.2	610.8		
40	153.6	395.7	666.4		
45	166.7	440.0	762.2		
50	162.3	543.2	823.6		
54	165.3	562.1	871.9		

Table B1 (contd)

SAND STORM NO. 23

DATE: 16 Aug 63

TIME (seconds)	POSITION OF TOP Z (feet)	Y (feet)	X (feet)	WIDTH (feet)	LENGTH (feet)
0	9.9	8.7	28.5	11.2	
1	23.2	28.2	84.5	35.9	
2	37.7	33.9	110.5	47.0	
3	45.1	38.6	136.1	47.3	
4	49.7	43.6	160.5	54.6	
5	51.3	47.0	182.9	53.7	
6	50.5	61.8	252.7	58.2	
7	53.4	64.5	275.4	63.2	
8	55.8	72.1	302.7	69.5	
9	56.0	75.3	326.5	72.6	
10	57.6	80.6	356.0	79.6	
11	56.5	84.3	371.9	86.3	
12	57.0	93.0	410.4	84.5	
13	57.1	96.6	439.1	94.8	
14	58.8	101.6	472.4	96.7	
15	60.6	104.4	481.8	107.4	
16	62.2	106.4	517.1	112.4	
17	61.7	108.9	537.2	118.3	
18	63.7	117.3	567.7		
19	64.2	119.4	593.1		
20	64.4	126.9	619.4		
25	69.8	107.0	740.6		
27	75.0	119.2	811.4		

Table B1 (contd)

SAND STORM NO. 25

DATE: 21 Aug 63

TIME (seconds)	POSITION OF TOP Z (feet)	Y (feet)	X (feet)	WIDTH (feet)	LENGTH (feet)
0	3.6	2.9	5.8	5.8	
1	17.1	28.9	91.3	43.9	
2	28.4	25.0	120.6	65.3	
3	36.1	48.6	145.3	71.0	
4	44.1	58.0	165.6	86.5	
5	47.0	61.5	184.5	87.4	
6	52.6	72.4	203.7	101.6	
7	53.7	80.1	225.8	111.3	
8	55.0	85.1	247.3	118.0	
9	57.2	89.4	268.0		
10	63.9	93.2	285.6		
11	67.2	100.7	302.2		
12	69.3	111.5	321.2		
13	71.3	118.9	341.5		
14	74.0	127.9	360.0		
15	77.0	155.3	406.9		
16	83.9	168.8	440.9		
17	89.5	177.8	455.9		
18	97.1	192.1	478.2		
19	105.7	203.7	500.1		
20	113.6	210.4	521.6		
25	160.1	260.3	623.9		
30	201.5	300.5	730.3		

Table B1 (contd)

SAND STORM NO. 26

DATE: 22 Aug 63

TIME	POSITION OF TOP			WIDTH	LENGTH
	Z	Y	X		
(seconds)	(feet)	(feet)	(feet)	(feet)	(feet)
1	21.4	10.3	81.0		
2	30.8	6.6	163.2		
3	43.5	8.8	199.8		
4	54.0	10.0	249.8		
5	64.1	12.6	288.5		
6	71.4	9.3	324.7		
7	72.4	14.9	364.5		
8	76.5	19.2	416.2		
9	78.1	3.3	440.7		
10	77.2	4.4	478.8		
11	86.2	-3.5	519.7		
12	89.0	.0	550.7		
13	93.4	.8	583.2		
14	94.8	-2.2	618.5		
15	98.2	1.4	656.1		
16	97.7	4.5	689.2		
17	101.4	7.5	727.5		
18	104.1	25.1	829.6		
19	110.9	25.1	873.0		
20	111.2	28.3	913.2		
25	124.4	39.8	1120.1		
29	135.6	40.2	1263.4		

Table B1 (contd)

SAND STORM NO. 27

DATE: 27 Aug 63

TIME	POSITION OF TOP			WIDTH	LENGTH
	Z	Y	X		
(seconds)	(feet)	(feet)	(feet)	(feet)	(feet)
0	8.0	8.3	45.4	13.7	
1	20.7	19.8	100.2	38.5	
2	34.1	24.5	127.8	64.3	
3	41.2	26.0	147.6	80.4	
4	43.5	31.1	164.0	93.3	
5	46.1	30.4	179.1	101.3	
6	47.2	38.5	245.2	110.0	
7	51.0	41.8	310.8	121.9	
8	57.7	45.5	334.4	138.1	
9	62.0	46.8	358.7	146.5	
10	67.2	44.4	339.7	151.8	
11					
12					
13	84.5	38.6	463.7	167.8	
14	87.9	46.6	488.5	160.6	
15	92.7	51.3	512.0	174.2	
16	96.9	44.1	539.0	181.1	
17	101.3	40.9	563.6	189.5	
18	106.4	44.0	587.5	190.2	
19	110.4	38.1	606.5		
20	114.8	44.2	630.6		
25	131.7	23.3	771.4		
30	147.7	15.6	844.3		
35	164.8	26.1	965.2		
40	[illegible]	-18.8	[illegible]		
45	[illegible]	-22.7	1198.0		
50	238.2	-19.9	1307.9		
55	260.2	- 6.5	1439.1		
60	271.0	-10.5	1558.4		
65	278.6	.6	1687.9		
70	289.9	- 1.7	1816.2		
75	304.4	3.8	1959.5		
80	307.5	10.5	2099.7		
85	312.5	19.8	2196.4		
90	321.3	19.8	2313.2		
95	331.1	13.1	2451.6		
98	341.4	21.9	2529.3		

Table B1 (contd)

SAND STORM NO. 28

DATE: 30 Aug 63

TIME	POSITION OF TOP			WIDTH	LENGTH
	Z	Y	X		
(seconds)	(feet)	(feet)	(feet)	(feet)	(feet)
0	11.2	6.6	34.7	18.5	
1	20.5	10.7	89.0	37.6	
2	29.7	23.1	132.3	62.3	
3	30.2	35.8	168.5	71.1	
4	38.5	40.5	209.2	77.9	
5	46.1	45.0	234.7	90.0	
6	53.2	49.4	266.1	96.0	
7	60.1	56.6	284.4	104.1	
8	65.6	62.8	316.9	112.6	
9	73.3	64.3	342.3		
10	78.9	67.9	368.6		
11	85.8	74.7	388.2	115.0	
12	94.0	76.7	417.7	118.5	
13	95.9	87.1	438.2	120.7	
14	101.5	92.7	461.6	125.2	
15	106.0	98.1	488.1	130.0	
16	113.9	103.9	515.6		
17	119.0	111.3	540.5		
18	119.9	116.8	566.7		
19	127.4	120.2	591.8	138.9	
20	136.6	124.3	613.9	139.7	
25	164.5	145.4	722.6	155.7	
30	208.3	170.5	828.2		
35	254.7	107.0	964.3		

Table B1 (contd)

SAND STORM NO. 29

DATE: 10 Sept 63

TIME	POSITION OF TOP			WIDTH	LENGTH
	Z	Y	X		
(seconds)	(feet)	(feet)	(feet)	(feet)	(feet)
0	6.2	7.2	28.7		
1	26.8	15.4	78.1		
2	35.3	21.8	139.9		
3	47.8	25.4	160.5		
4	55.3	32.4	183.8		
5	60.4	38.5	207.6		
6	63.7	45.2	230.0		
7	67.4	54.1	260.7		
8	71.1	64.3	307.5		
9	79.4	82.8	328.3		
10	87.8	84.7	352.9		
11	94.4	102.6	376.6		
12	102.5	98.8	406.4		
13	108.8	114.4	440.4		
14	120.3	120.0	474.4		
15	125.7	130.0	506.1		
16	124.3	144.5	539.7		
17	130.5	155.9	563.2		
18	139.3	170.8	600.2		
19	148.6	179.8	632.8		
20	152.0	193.3	665.5		
25	181.2	227.9	812.2		

Table B1 (contd)

SAND STORM NO. 30

DATE: 11 Sept 1963

TIME	POSITION OF TOF			WIDTH	LENGTH
	Z	Y	X		
(seconds)	(feet)	(feet)	(feet)	(feet)	(feet)
0	2.6	5.5	21.1		
1	23.5	24.6	88.4		
2	34.0	35.2	106.8		
3	38.1	47.7	143.5		
4	41.9	56.2	174.2		
5	48.2	63.7	194.7		
6	59.0	72.5	213.2		
7	68.1	77.4	226.9		
8	77.0	86.7	238.1		
9	64.3	94.2	248.5		
10	68.1	100.9	261.7		
11	67.5	107.9	279.7		
12	72.6	113.3	297.4		
13	77.0	121.6	311.2		
14	81.0	129.9	327.6		
15	81.0	140.0	350.7		
16	85.6	145.0	367.1		
17	93.2	145.0	377.8		
18	100.8	165.0	398.9		
19	106.1	170.5	412.3		
20	111.9	181.8	424.9		
25	134.6	209.0	494.8		
30	162.8	240.0	559.7		
35	193.2	301.5	620.4		
40	218.9	335.1	666.0		
45	235.8	367.5	725.0		
50	254.3	409.3	807.8		
55	273.8	452.9	871.3		
60	293.6	497.8	937.7		
65	312.0	534.3	1004.2		
70	327.3	558.9	1082.2		
75	339.3	585.6	1159.6		

Table B1 (contd)

SAND STORM NO. 31

DATE: 12 Sept 63

TIME	POSITION OF TOP			WIDTH	LENGTH
	Z	Y	X		
(seconds)	(feet)	(feet)	(feet)	(feet)	(feet)
0	5.3	6.8	25.9	6.4	
1	21.7	19.4	84.3	37.5	
2	29.2	40.8	146.3	55.5	
3	38.5	50.8	184.2	68.1	
4	48.2	67.7	224.6	81.3	
5	57.0	78.4	250.7	94.7	
6	66.4	88.5	276.0	103.3	
7	71.0	102.0	309.5	111.9	
8	77.2	112.9	337.7	126.5	
9	84.9	127.2	366.2	129.7	
10	89.0	173.8	385.5	138.2	
11	96.4	175.1	421.6	139.0	
12	102.9	188.5	451.9	144.1	
13	110.5	210.9	482.8	150.9	
14	119.5	232.7	513.3	160.5	
15	126.2	254.7	548.0	169.1	
16	135.7	285.9	617.1	181.5	
17	135.5	288.6	609.8	184.9	
18	141.9	313.1	642.7	200.4	
19	147.3	329.1	632.5	210.1	
20	149.3	347.6	706.4	222.4	
25	166.0	435.3	866.7		
30	177.8	498.9	1042.3		
35	196.3	628.2	1180.3		
40	219.8	734.6	1338.9		

Table B1 (contd)

SAND STORM NO. 32

DATE: 16 Sept 63

TIME (seconds)	POSITION OF TOP Z (feet)	POSITION OF TOP Y (feet)	POSITION OF TOP X (feet)	WIDTH (feet)	LENGTH (feet)
0	12.0	8.0	37.3		
1	25.0	22.6	88.3		
2	32.0	37.9	142.1		
3	39.2	45.4	175.5		
4	47.0	54.0	205.3		
5	51.4	65.5	239.9		
6	58.2	76.1	267.5		
7	65.4	84.3	297.6		
8	70.2	88.8	319.0		
9	75.0	98.9	342.8		
10	79.3	111.7	378.2		
11	85.3	121.8	404.1		
12	93.6	135.9	432.2		
13	99.0	145.6	457.3		
14	104.4	153.0	474.9		
15	111.2	167.9	505.0		
16	117.0	180.5	530.1		
17	122.2	192.7	554.5		
18	127.7	203.1	589.2		
19	133.6	213.9	611.3		
20	139.5	222.1	639.0		
25	175.9	283.4	771.3		
30	198.6	327.5	898.1		
35	230.8	382.7	1048.2		
40	245.6	422.4	1181.1		
42	246.6	449.1	1234.9		

Table B1 (contd)

SAND STORM NO. 34

DATE: 9 Oct 63

TIME (seconds)	POSITION OF TOP Z (feet)	Y (feet)	X (feet)	WIDTH (feet)	LENGTH (feet)
0	17.0	18.8	76.5	29.4	23.5
1	32.3	26.8	103.2	42.3	33.6
2	33.5	34.2	143.7	65.5	60.6
3	39.1	39.2	151.3	69.8	78.0
5	48.4	47.6	192.6	81.6	111.3
6	54.3	62.2	228.1	90.6	
7	61.5	66.1	251.1		127.4
8	65.0	66.7	275.7	96.3	
9	69.5	73.9	297.2	102.8	133.4
10	77.3	78.9	310.2		139.1
11	83.0	82.0	327.2		151.5
12	92.4	89.2	347.4		
13	99.5	90.7	366.3		
14	107.4	97.0	383.6		
15	115.7	105.2	396.3		
16	124.8	111.0	416.5		
17	132.4	116.3	432.5		
18	140.8	122.7	448.9		
19	148.7	131.2	468.9		
20	157.4	134.4	485.7		
25	210.2	159.1	585.5		
30	255.5	161.2	670.6		
35	293.1	190.1	762.1		
40	332.9	216.2	852.9		
45	368.2	252.4	958.7		
50	397.1	268.9	1008.7		
60	468.8	330.7	1229.2		
65	504.6	342.2	1261.6		
70	558.9	359.6	1365.3		
73	596.0	382.1	1418.9		

Table B1 (cont'd)

SAND STORM NO. 37

DATE: 22 Oct 63

TIME	POSITION OF TOP			WIDTH	LENGTH
	Z	Y	X		
(seconds)	(feet)	(feet)	(feet)	(feet)	(feet)
0	15.4	10.3	32.7		38.3
1	22.8	30.1	98.5		108.6
2	30.2	46.1	151.0		151.4
3	37.9	54.4	177.2		182.1
5	51.4	58.6	234.7		252.1
6	62.6	60.9	243.9		289.3
7	71.9	75.0	292.3		320.6
8	69.8	88.0	331.3		329.7
9	75.4	102.7	345.2		339.2
10	82.8	109.2	367.0		
11	89.4	76.8	383.3		
12	92.9	78.0	407.2		
13	99.5	82.9	439.9		
14	106.6	94.6	463.2		
15	114.9	94.7	458.2		
16	125.6	100.0	491.3		
17	130.5	107.5	534.9		
18	112.9	144.1	538.4		
19	114.7	152.0	566.3		
20	123.4	158.2	574.7		
25	151.8	177.2	696.5		
29	180.5	207.8	792.6		

SAND STORM NO. 39

DATE: 23 Oct 63

TIME (seconds)	POSITION OF TOP Z (feet)	POSITION OF TOP Y (feet)	POSITION OF TOP X (feet)	WIDTH (feet)	LENGTH (feet)
1	44.9	50.3	183.3	77.0	
2	36.5	57.6	216.1	96.1	
3	42.7	66.7	249.6	108.2	
4	58.2	75.7	285.1	112.6	
5	45.0	89.8	317.0	117.1	
6	65.0	103.7	348.0	120.4	
7	72.9	112.8	380.8	126.5	
8	81.1	131.9	412.4	132.0	
9	87.3	142.7	442.4	139.5	
10	93.2	156.9	472.2	151.6	
11	99.6	166.6	501.2	156.2	
12	106.4	183.0	532.5	168.1	
13	111.4	198.5	563.0	175.5	
14	116.1	211.[illegible]	591.9	179.6	
15	118.8	225.3	623.2	175.1	
16	125.4	236.5	650.5	177.0	
17	127.9	244.6	684.5	178.0	
18	130.4	255.9	71[illegible].8		
19	132.9	262.7	752.9		
20	137.3	271.7	781.4	188.2	
25	146.7	340.4	938.2	222.5	
30	160.0	398.3	1105.6	252.0	
35	168.4	463.8	1258.0		
40	180.0	525.5	1394.0		

Table B1 (contd)

SAND STORM NO. 39
DATE: 29 Oct 63

TIME	POSITION OF TOP			WIDTH	LENGTH
	Z	Y	X		
(seconds)	(feet)	(feet)	(feet)	(feet)	(feet)
0	13.8	6.6	28.7	23.1	21.5
1	20.9	10.9	77.2	40.9	35.3
2	21.8	19.8	104.9	49.0	63.8
3	27.7	25.2	149.0	58.3	71.8
4	37.2	35.9	165.2	61.8	81.2
5	44.8	36.7	180.1	66.4	76.9
6	49.7	39.0	188.0	70.5	102.4
7	56.8	42.9	198.0	74.2	108.6
8	60.9	45.0	210.4	80.7	114.6
9	66.2	47.8	223.1	81.5	121.4
10	70.7	50.4	233.3	86.2	142.0
11	75.5	52.5	244.1	90.4	151.9
12	78.2	53.7	264.1		164.1
13	75.6	60.0	268.9		166.5
14	78.7	55.4	280.5		173.9
15	85.2	59.5	292.5		181.0
16	91.1	64.3	317.1		184.6
17	96.3	69.7	354.3		184.7
18	101.5	71.1	372.8		191.5
19	105.9	69.5	385.2		
20	111.1	70.5	396.8		195.2
25	133.9	64.8	499.6		
30	162.0	80.2	579.4		
35	184.2	82.2	661.9		
40	207.5	91.6	738.2		
45	226.3	67.8	804.3		
50	248.5	49.9	870.3		
55	275.6	72.3	929.9		
60	298.0	62.1	999.5		
65	322.4	65.5	1079.7		
69	342.6	43.8	1125.3		

Table B1 (contd)

SAND STORM NO. 40

DATE: 30 Oct 63

TIME	POSITION OF TOP			WIDTH	LENGTH
	Z	Y	X		
(seconds)	(feet)	(feet)	(feet)	(feet)	(feet)
0	10.7	7.7	44.1	17.5	
1	19.2	19.4	98.0	29.5	
2	30.7	33.8	128.2	42.6	
3	37.1	43.5	164.4	49.6	
4	44.7	52.5	195.0	54.5	
5	49.6	58.2	223.4	56.0	
6	54.5	6[illegible]	252.1		
7	56.5	72.[illegible]	278.3	63.3	
8	59.6	79.7	306.7	69.5	
9	66.4	84.1	327.6		
10	70.2	88.7	353.0	73.4	
11					
12					
13	81.6	90.[illegible]	430.5	78.6	
14	89.3	97.6	457.8		
15	95.8	97.2	484.7	82.7	
16	101.9	103.1	512.4		
17	105.9	108.7	541.4		
18	113.7	117.4	569.2	85.4	
19					
20	118.9	131.2	617.6	89.1	
25					
29	151.3	207.1	889.6	99.6	

Table B1 (contd)

SAND STORM NO. 41

DATE: 4 Nov 63

TIME (seconds)	POSITION OF TOP Z (feet)	POSITION OF TOP Y (feet)	POSITION OF TOP X (feet)	WIDTH (feet)	LENGTH (feet)
0	24.0	20.8	80.0	27.8	
1	25.3	34.8	130.6	44.7	
2	30.9	49.0	177.8	53.3	
3	37.4	57.7	218.5	59.0	
4	41.3	63.8	256.2	74.6	
5	45.6	69.6	288.7	81.8	
6	48.7	71.0	296.9	94.9	
7	53.0	73.4	329.0	98.5	
8	57.2	81.0	358.5	105.0	
9	58.1	84.4	393.5	119.7	
10	66.2	93.1	424.5		
11	70.5	101.2	458.3	131.1	
12	76.1	103.7	485.6	133.7	
13	80.3	103.7	510.6	135.1	
14	87.3	108.0	538.1	139.1	
15	92.6	117.4	566.1		
16	97.1	122.7	598.7	140.5	
17	101.7	126.6	630.1		
18	107.7	130.5	654.7		
19	113.3	138.4	689.7		
20	120.8	140.9	719.6		
25	145.6	139.7	878.4		
30	153.6	159.7	1051.1		
35	166.8	148.0	1211.4		
40	173.9	160.1	1377.9		
45	18[illegible].1	169.4	1541.8		
50	191.7	179.4	1713.6		
52	198.7	182.7	1768.3		

Table B1 (contd)

SAND STORM NO. 42

DATE: 5 Nov 1963

TIME	POSITION OF TOP			WIDTH	LENGTH
	Z	Y	X		
(seconds)	(feet)	(feet)	(feet)	(feet)	(feet)
0	13.6	10.9	40.0	18.8	
1	24.4	21.1	92.4	39.1	
2	34.4	26.9	119.6	[illegible]	
3	45.7	44.5	167.5	68.6	
4	42.1	54.8	217.9	76.3	
5	55.2	55.4	249.4	89.0	
6	78.2	58.5	279.8	96.4	
7	72.6	62.2	294.8	110.6	
9	81.9	66.6	362.0	126.7	
10	90.5	70.8	385.2		
11	98.3	68.7	425.0	134.5	
12	103.9	73.9	455.0	144.6	
13	112.0	82.4	493.1	147.1	
14	119.4	98.9	541.9	159.4	
15	125.0	93.1	579.1	166.4	
16	127.3	91.5	607.7	167.0	
17	132.7	95.0	644.0	168.5	
18	140.7	90.9	670.7		
19	150.8	97.4	713.3	179.9	
20	151.9	106.5	747.6		
25	181.1	133.9	957.1	185.7	
30	210.1	143.9	1144.0		
35	223.4	162.6	1347.7		
40	248.9	161.1	1481.5		
43	265.4	177.3	1611.8		

Table B1 (contd)

SAND STORM NO. 43

DATE: 7 Nov 63

TIME	POSITION OF TOP			WIDTH	LENGTH
	Z	Y	X		
(seconds)	(feet)	(feet)	(feet)	(feet)	(feet)
0	17.4	10.7	42.6	19.1	
1	27.1	21.0	89.4	34.9	
2	34.0	27.7	128.5		
3	44.2	26.1	148.4	47.9	
4	55.6	29.5	165.6	54.2	
5	65.3	36.4	194.2	63.4	
6	74.4	41.3	228.5	70.1	
7	82.2	46.6	253.8	78.9	
8	90.3	46.5	277.2	86.7	
9	96.8	56.6	305.6	92.3	
10	103.7	57.5	325.6	101.0	
11	108.5	60.7	346.3	111.3	
12	113.8	65.7	373.0	122.6	
13	116.6	73.4	395.4	133.8	
14	119.8	74.9	428.1	147.0	
15	123.4	75.7	452.1	153.3	
16	128.9	81.1	482.7	157.4	
17	129.9	85.7	503.2	160.5	
18	136.6	95.1	540.4	164.8	
19	141.8	102.2	565.3	175.7	
20	144.6	114.3	597.4	187.0	
25	169.8	137.3	715.3	221.0	
30	195.3	149.4	819.5	260.2	
35	213.3	171.4	946.5	304.7	
40	238.3	209.3	1071.9	338.7	

Appendix C

Variance of Wind Direction Fluctuations

The tabulations contained in this appendix show the variances of wind azimuth fluctuations for various smoothing and sampling intervals. The mathematical filters used to obtain the data are explained in Chapter VI of the report. The instrumentation used to collect the data is described in Chapter IV. The variances, shown in units of degrees squared, are computed from 10 minutes of record beginning 3 minutes before firing. The wind direction and speed are mean values for the same period and are in units of degrees true azimuth and meters per second.

Table C1. Varianc? of Wind Direction Fluctuations

$\sigma^2(\theta)_{T,s}$
(degrees)

SAND STORM NO. 2
DATE 27 Mar 1963
TIME 1130 PST

12 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	24.5	30.6	38.6	48.7	49.6	64.6
2	20.1	26.5	34.6	44.8	45.8	60.7
4	13.3	20.4	28.7	39.0	40.2	54.9
8	4.7	12.5	21.2	31.9	33.2	47.6
16	0	3.7	12.3	23.6	25.0	39.1

MEAN DIRECTION AND SPEED 226/10.3

50 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1						
2						
4			M I S S I N G			
8						
16						

100 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	9.1	13.5	18.4	25.1	26.4	40.0
2	8.1	12.7	17.6	24.4	25.7	39.3
4	5.9	10.7	15.8	22.7	24.1	37.6
8	2.2	7.2	12.5	19.5	21.0	34.6
16	0	2.4	7.8	15.1	17.0	30.1

MEAN DIRECTION AND SPEED 248/10.4

200 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	5.0	8.2	12.0	15.9	18.6	33.4
2	4.5	7.8	11.6	15.5	18.3	33.1
4	3.3	6.8	10.7	14.8	17.6	32.3
8	1.3	4.8	8.9	13.2	16.2	30.6
16	0	1.7	5.8	10.4	13.7	27.6

MEAN DIRECTION AND SPEED 253/11.7

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Table C1 (contd)

$\sigma^2(\theta)_{T,s}$
(degrees)

SAND STORM NO. 3
DATE 8 Apr 1963
TIME 1040 PST

12 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	15.5	20.2	27.1	37.0	46.5	46.3
2	12.7	17.6	24.5	34.5	44.0	44.0
4	8.5	13.7	20.8	30.8	40.6	40.7
8	2.9	8.4	15.6	25.8	36.2	36.3
16	0	2.7	9.7	20.2	31.4	31.7

MEAN DIRECTION AND SPEED 277/11.0

50 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	13.0	18.1	24.4	32.2	39.8	39.5
2	11.0	16.3	22.7	30.6	38.3	38.0
4	7.6	13.2	19.9	28.0	36.0	35.5
8	2.7	8.5	15.5	23.9	32.2	31.9
16	0	2.7	9.6	18.3	27.1	27.2

100 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	10.2	14.2	19.4	27.7	35.1	35.3
2	8.7	12.8	18.1	26.4	33.9	34.2
4	6.0	10.3	15.6	24.1	31.9	32.1
8	2.1	6.5	11.9	20.7	29.1	29.2
16	0	2.1	7.4	16.4	25.9	25.9

MEAN DIRECTION AND SPEED 274/12.6

200 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	5.3	8.8	12.8	18.4	23.4	25.1
2	4.7	8.2	12.4	18.0	23.0	24.7
4	3.4	7.1	11.4	17.1	22.3	24.0
8	1.3	4.9	9.4	15.3	20.8	22.5
16	0	1.8	6.3	12.5	18.5	20.1

MEAN DIRECTION AND SPEED 265/13.5

Table C1 (contd)

$\sigma^2(\theta)_{T,s}$
(degrees)

SAND STORM NO. 4
DATE 19 Apr 1963
TIME 1314 PST

12 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	19.2	28.8	40.4	53.8	64.6	80.3
2	16.1	26.0	37.8	51.2	62.2	77.9
4	11.1	21.3	33.6	47.1	58.3	74.3
8	3.9	13.9	27.0	40.8	52.3	68.8
16	0	5.1	18.2	32.5	44.4	62.0

MEAN DIRECTION AND SPEED 253/13.7

50 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	12.5	19.2	26.0	31.0	39.6	60.5
2	10.6	17.5	24.5	29.6	38.1	59.1
4	7.4	14.5	22.0	27.1	35.6	56.8
8	2.8	9.8	18.1	23.5	32.0	53.5
16	0	3.5	12.2	18.1	26.7	48.6

100 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	11.6	19.2	27.9	36.4	48.6	61.3
2	10.0	17.6	26.5	35.1	47.2	60.2
4	7.0	14.8	24.1	32.7	44.8	58.2
8	2.7	10.1	20.1	28.8	40.8	55.0
16	0	3.7	13.9	23.0	34.9	50.2

MEAN DIRECTION AND SPEED 248/14.8

200 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	6.2	10.7	14.7	18.1	27.8	43.9
2	5.4	9.9	14.2	17.6	27.2	43.4
4	3.9	8.5	13.1	16.6	26.2	42.5
8	1.6	6.0	11.2	14.7	24.3	40.9
16	0	2.2	7.8	11.4	20.9	38.0

MEAN DIRECTION AND SPEED 264/17.2

Table C1 (contd)

$\sigma^2(\theta)_{T,s}$
(degrees)

SAND STORM NO. 5
DATE 24 Apr 1963
TIME 1531 PST

12 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	24.7	33.2	48.6	68.0	74.5	101.2
2	20.6	29.1	44.6	64.4	71.2	97.8
4	13.9	22.6	38.2	58.9	66.2	92.5
8	4.5	13.2	28.7	50.8	59.1	85.0
16	0	4.4	18.6	42.3	52.1	77.9

MEAN DIRECTION AND SPEED 253/5.9

50 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	13.5	22.2	39.1	60.9	65.8	88.9
2	11.5	20.2	37.1	59.3	64.3	87.4
4	8.1	16.9	33.7	56.5	62.0	85.1
8	3.1	11.5	28.1	52.0	58.7	81.3
16	0	4.2	15.4	44.8	53.6	75.4

100 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	8.4	16.3	32.1	54.3	56.9	74.8
2	7.3	15.2	31.0	53.4	56.3	74.1
4	5.4	13.2	29.0	51.8	55.2	73.0
8	2.2	9.4	25.0	48.6	53.0	70.8
16	0	3.6	17.8	42.2	48.8	66.4

MEAN DIRECTION AND SPEED 269/9.5

200 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	10.3	16.0	28.0	48.8	52.1	67.8
2	8.9	14.7	26.7	47.7	51.2	66.8
4	6.4	12.2	24.3	45.4	49.6	65.1
8	2.3	8.0	20.1	41.5	46.8	62.0
16	0	2.9	14.1	35.7	43.2	58.0

MEAN DIRECTION AND SPEED 265/9.8

Table C1 (contd)

$\sigma^2(\theta)_{T,s}$
(degrees)

SAND STORM NO. 6
DATE 6 May 1963
TIME 1420 PST

12 Feet

T (sec)

s (sec)	16	32	64	128	256	512
1	42.4	60.1	82.1	123.8	169.9	270.2
2	33.9	52.1	74.3	116.3	163.2	262.9
4	23.1	42.0	64.7	107.1	155.3	254.2
8	8.2	27.1	50.7	93.3	144.0	241.5
16	0	3.4	33.0	75.3	130.6	225.2

MEAN DIRECTION AND SPEED 246/3.9

50 Feet

T (sec)

s (sec)	16	32	64	128	256	512
1						
2			M I S S I N G			
4						
8						
16						

100 Feet

T (sec)

s (sec)	16	32	64	128	256	512
1	24.5	39.4	59.8	91.7	133.5	241.7
2	21.1	36.2	56.8	88.8	130.7	238.8
4	15.0	30.5	51.4	83.5	125.7	233.5
8	5.6	20.8	42.1	74.3	117.3	224.3
16	0	7.6	23.4	60.9	105.5	210.4

MEAN DIRECTION AND SPEED 256/5.9

200 Feet

T (sec)

s (sec)	15	32	64	128	256	512
1	79.3	133.7	214.1	311.6	401.2	627.7
2	69.7	[illegible]	206.4	304.9	395.5	622.7
4	50.8	108.6	190.8	291.2	383.8	612.5
8	20.9	77.7	161.4	265.7	362.2	593.5
16	0	28.0	107.9	218.6	323.5	558.0

MEAN DIRECTION AND SPEED 236/7.2

Table C1 (contd)

$\sigma^2(\theta)_{T,s}$
(degrees)

SAND STORM NO. 7
DATE 8 May 1963
TIME 0939 PST

12 Feet

T (sec)

s (sec)	16	32	64	128	256	512
1	22.3	28.3	33.7	37.4	40.1	38.5
2	18.3	24.6	30.2	34.1	36.8	35.2
4	12.3	19.1	25.3	29.3	32.1	30.5
8	4.1	11.5	18.6	23.0	26.1	24.5
16	0	3.7	11.6	16.6	20.0	18.6

MEAN DIRECTION AND SPEED 253/7.6

50 Feet

T (sec)

s (sec)	16	32	64	128	256	512
1	15.4	20.3	25.4	31.0	37.4	35.3
2	13.2	18.3	23.6	29.3	35.8	33.6
4	9.0	14.6	20.3	26.2	32.7	30.7
8	3.2	9.2	15.4	21.6	28.4	26.4
16	0.	2.9	9.4	15.8	23.1	21.3

100 Feet

T (sec)

s (sec)	16	32	64	128	256	512
1	18.2	22.0	26.4	32.1	40.5	36.9
2	16.0	20.0	24.6	30.4	38.8	35.2
4	11.6	16.2	21.0	27.1	35.4	31.9
8	4.2	9.8	14.8	21.1	29.1	26.1
16	0	2.4	7.5	13.8	21.3	19.5

MEAN DIRECTION AND SPEED 244/13.4

200 Feet

T (sec)

s (sec)	16	32	64	128	256	512
1	9.2	14.1	18.2	21.4	25.3	22.9
2	8.1	13.2	17.3	20.7	24.5	22.1
4	5.9	11.2	5.7	19.1	22.8	20.7
8	2.2	7.6	12.7	16.2	19.7	17.9
16	0	2.7	8.2	11.9	15.0	13.0

MEAN DIRECTION AND SPEED 246/15.7

Table C1 (contd)

$\sigma^2(\theta)_{T,s}$
(degrees)

SAND STORM NO. 8
DATE 22 May 1963
TIME 1332 PST

12 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	37.3	55.4	82.7	126.8	189.5	332.6
2	30.8	49.3	77.0	121.3	184.5	327.3
4	21.4	40.6	68.8	113.5	177.2	320.0
8	8.2	27.5	56.7	102.0	166.7	309.4
16	0	9.9	38.2	84.6	151.2	293.1

MEAN DIRECTION AND SPEED 250/6.6

50 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	39.1	65.9	100.3	155.0	200.7	341.0
2	33.8	61.2	95.9	150.6	196.3	336.8
4	24.6	53.2	88.4	143.0	188.9	329.7
8	10.2	38.4	74.7	129.3	175.7	316.6
16	0	14.0	49.7	104.2	152.8	291.7

100 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	22.2	35.6	51.1	76.1	118.6	221.6
2	19.6	33.2	49.0	74.0	116.6	219.8
4	14.2	28.4	44.7	69.7	112.4	216.0
8	5.6	19.6	36.9	61.7	104.6	208.9
16						

MEAN DIRECTION AND SPEED 265/7.6

200 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	13.2	20.6	29.2	40.5	62.3	138.5
2	11.6	19.1	27.8	39.2	61.0	137.3
4	8.4	16.0	25.2	36.6	58.5	134.8
8	3.2	10.6	20.5	31.8	53.9	130.2
16	0	3.7	13.8	24.8	47.1	123.5

MEAN DIRECTION AND SPEED 249/10.6

Table C1 (contd)

$\sigma^2(\theta)_{T,s}$
(degrees)

SAND STORM NO. 9
DATE 23 May 1963
TIME 1311 PST

12 Feet

T (sec)

s (sec)	16	32	64	128	256	512
1	20.3	26.3	33.9	39.5	45.9	47.9
2	16.0	22.3	30.2	35.9	42.3	44.3
4	10.3	17.0	25.2	31.1	37.5	39.6
8	3.5	10.6	19.2	25.7	32.2	34.3
16	0	3.5	12.2	19.9	26.6	28.6

MEAN DIRECTION AND SPEED 267/9.1

50 Feet

T (sec)

s (sec)	16	32	64	128	256	512
1	11.2	14.8	18.6	13.9	22.3	23.9
2	9.3	13.2	17.1	18.5	20.9	22.5
4	6.5	10.5	14.8	15.4	18.8	20.3
8	2.2	6.5	11.3	13.2	15.6	17.1
16	0	2.1	7.2	9.8	12.4	13.5

100 Feet

T (sec)

s (sec)	16	32	64	128	256	512
1	11.1	15.0	19.0	18.7	17.0	21.7
2	9.4	13.4	17.6	17.5	15.9	20.4
4	6.5	10.8	15.3	15.7	14.1	18.4
8	2.4	7.0	11.9	13.1	11.5	15.5
16	0	2.3	7.5	9.8	8.4	11.9

MEAN DIRECTION AND SPEED 272/13.6

200 Feet

T (sec)

s (sec)	16	32	64	128	256	512
1	8.7	12.5	16.7	17.1	15.8	20.1
2	7.3	11.1	15.4	15.9	14.6	18.8
4	4.9	8.8	13.4	14.2	12.8	16.9
8	1.7	5.6	10.6	11.8	10.4	14.3
16	0	1.9	7.0	9.0	7.9	11.2

MEAN DIRECTION AND SPEED 270/16.0

Table C1 (contd)

$\sigma^2(\theta)_{T,s}$
(degrees)

SAND STORM NO. 10
DATE 29 May 1963
TIME 1352 PST

12 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	31.0	47.2	67.0	88.0	94.6	105.9
2	26.5	43.7	64.1	85.5	92.3	103.5
4	19.2	37.7	58.9	81.1	88.4	99.5
8	7.6	26.6	49.3	72.7	80.8	92.2
16	0	9.4	32.6	57.4	67.2	79.2

MEAN DIRECTION AND SPEED 251/6.2

50 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	24.6	31.3	41.5	55.3	57.6	70.7
2	20.9	28.1	38.6	52.9	55.6	68.4
4	14.6	22.7	33.7	48.9	52.1	64.5
8	5.3	14.5	26.2	42.7	46.9	58.8
16	0	4.5	16.6	34.3	39.8	51.9

100 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	26.2	37.9	45.3	54.1	69.5	82.0
2	22.4	34.7	42.6	51.3	66.8	79.5
4	15.8	29.1	38.1	46.6	62.1	75.2
8	6.0	19.9	30.5	39.0	54.8	68.3
16	0	6.8	18.8	27.7	43.9	58.0

MEAN DIRECTION AND SPEED 267/6.4

200 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	25.9	35.6	48.7	64.6	89.0	110.1
2	22.2	32.2	45.5	61.5	85.8	107.3
4	15.8	26.5	40.0	56.1	80.5	102.5
8	5.8	17.0	31.0	47.2	71.6	94.7
16	0	5.4	19.0	35.6	60.0	85.0

MEAN DIRECTION AND SPEED 257/missing

Table C1 (contd)

$\sigma^2(\theta)_{T,s}$
(degrees)

SAND STORM NO. 11
DATE 10 June 1963
TIME 0914 PST

12 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	11.1	15.8	20.4	24.7	30.0	30.3
2	9.4	14.3	19.0	23.3	28.6	29.0
4	6.5	11.8	16.8	21.1	26.4	26.9
8	2.4	7.9	13.3	17.7	23.0	23.8
16	0	2.7	8.3	13.0	18.3	19.5

MEAN DIRECTION AND SPEED 234/12.5

50 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	15.3	20.2	24.1	28.8	32.5	34.5
2	12.8	18.0	22.0	26.7	30.4	32.5
4	8.8	14.6	18.7	23.5	27.2	29.4
8	3.2	9.5	13.9	18.9	22.4	25.0
16	0	3.0	7.9	13.1	16.4	19.6

100 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	11.1	15.1	18.1	21.1	27.1	29.7
2	9.5	13.7	16.8	19.9	25.9	28.5
4	6.6	11.3	14.5	17.8	23.8	26.4
8	2.4	7.3	11.0	14.5	20.5	23.1
16	0	2.4	6.4	10.2	16.0	19.0

MEAN DIRECTION AND SPEED 263/12.6

200 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	6.1	7.9	9.0	9.8	11.0	14.0
2	5.2	7.1	8.2	9.1	10.3	13.3
4	3.5	5.7	7.0	7.9	9.2	12.1
8	1.2	3.6	5.1	6.2	7.5	10.4
16	0	1.1	3.0	4.3	5.7	8.5

MEAN DIRECTION AND SPEED 255/14.2

Table C1 (contd)

$\sigma^2(\theta)_{T,s}$
(degrees)

SAND STORM NO. 12
DATE 12 June 1963
TIME 1018 PST

12 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	133.7	255.3	405.8	627.2	1019.8	1099.3
2	115.8	238.4	391.2	612.7	1005.8	1088.6
4	83.5	205.6	363.5	585.4	979.5	1068.6
8	35.1	150.3	314.2	537.5	936.3	1034.3
16	0	58.7	221.1	447.0	857.4	969.1

MEAN DIRECTION AND SPEED 269/2.3

50 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	104.5	177.8	268.1	372.9	636.1	632.3
2	81.2	154.5	246.6	350.4	610.7	612.7
4	53.2	125.7	221.5	324.7	583.1	591.8
8	20.7	87.3	189.7	293.0	550.6	568.3
16	0	34.5	137.5	242.4	498.0	532.7

100 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	68.2	104.3	149.8	210.3	321.9	303.3
2	57.7	94.4	140.5	200.6	311.3	294.9
4	40.1	77.7	124.9	184.4	294.2	281.2
8	14.8	51.4	100.9	159.5	268.1	260.6
16	0	18.7	68.2	126.6	232.6	234.5

MEAN DIRECTION AND SPEED 277/3.1

200 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	55.5	85.2	133.4	170.7	222.5	263.5
2	46.1	75.9	124.6	162.4	214.1	255.2
4	32.0	61.9	111.6	150.7	202.7	243.5
8	11.8	40.5	91.3	133.1	185.9	225.7
16	0	14.4	62.6	109.4	163.8	201.3

MEAN DIRECTION AND SPEED 269/3.8

Table C1 (contd)

$\sigma^2(\theta)_{T,s}$
(degrees)

SAND STORM NO. 13
DATE 14 June 1963
TIME 1057 PST

12 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	69.9	122.3	208.1	264.8	305.2	316.8
2	58.5	111.2	197.9	255.7	295.1	308.0
4	40.3	93.1	181.2	241.6	279.3	294.4
8	16.3	65.8	155.4	221.6	258.0	274.6
16	0	25.5	110.5	187.8	223.8	240.2

MEAN DIRECTION AND SPEED 275/2.9

50 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	49.5	81.2	139.0	175.6	225.2	253.5
2	41.6	73.4	132.1	169.7	219.3	247.7
4	28.8	60.6	120.8	160.2	209.8	238.3
8	10.7	40.7	102.1	145.2	194.9	223.7
16	0	15.5	72.9	123.4	174.5	202.6

100 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	54.6	80.9	110.1	132.5	155.2	181.0
2	45.0	71.9	101.9	124.3	145.9	173.1
4	32.5	60.5	92.0	114.8	135.6	163.7
8	12.7	40.9	74.6	98.5	118.2	147.5
16	0	13.7	47.7	74.1	92.5	122.5

MEAN DIRECTION AND SPEED 295/3.4

200 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	40.9	61.3	86.9	121.9	163.8	161.2
2	35.3	56.3	82.5	117.8	159.3	157.5
4	25.9	48.3	75.6	111.4	152.8	151.8
8	10.6	33.9	63.3	100.2	142.1	142.1
16	0	11.9	42.4	81.1	123.5	126.0

MEAN DIRECTION AND SPEED 283/4.0

Table C1 (contd)

$\sigma^2(\theta)_{T,s}$
(degrees)

SAND STORM NO. 14
DATE 19 June 1963
TIME 1018 PST

12 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	26.1	46.5	84.5	155.3	173.1	216.8
2	22.3	42.8	80.9	152.0	170.3	214.1
4	15.9	36.3	74.6	146.1	165.4	209.4
8	6.2	25.3	63.4	135.7	157.2	201.2
16	0	9.7	45.1	117.7	144.1	187.2

MEAN DIRECTION AND SPEED 275/5.3

50 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	15.5	28.1	53.0	104.4	112.5	147.5
2	13.5	26.1	51.0	102.5	111.1	146.0
4	9.8	22.4	47.1	98.9	108.4	143.1
8	3.9	15.7	40.0	92.2	103.7	137.8
16	0	6.0	28.1	80.0	96.0	128.0

100 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	15.9	25.5	52.9	106.9	110.6	153.4
2	14.1	24.6	50.9	105.1	109.3	152.0
4	10.5	21.1	47.1	101.8	107.1	149.2
8	4.1	14.3	39.4	94.7	102.4	143.4
16	0	5.0	27.0	82.2	94.6	133.1

MEAN DIRECTION AND SPEED 285/5.3

200 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	10.6	18.3	32.8	59.4	64.9	97.1
2	9.2	17.0	31.5	58.2	63.9	95.9
4	6.6	14.5	29.0	55.9	62.1	93.8
8	2.6	10.1	24.6	51.9	58.9	90.0
16	0	3.7	17.2	44.6	53.9	83.1

MEAN DIRECTION AND SPEED 275/5.6

Table C1 (contd)

$\sigma^2(\theta)_{T,s}$
(degrees)

SAND STORM NO. 16
DATE 9 July 1963
TIME 0950 PST

12 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	44.9	82.4	134.0	20[illegible].0	254.2	281.4
2	38.8	76.7	128.9	201.4	250.2	277.9
4	28.2	66.3	119.8	193.1	243.4	272.0
8	11.7	47.7	103.1	178.1	231.5	261.5
16	0	18.6	72.7	150.7	209.7	242.7

MEAN DIRECTION AND SPEED 270/4.5

50 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	34.1	50.0	71.5	103.6	130.5	161.1
2	29.5	46.1	67.9	100.2	127.6	158.2
4	21.5	39.4	61.7	94.5	122.8	153.6
8	8.7	27.4	50.6	84.2	114.0	145.2
16	0	9.2	32.1	66.7	99.0	13[illegible].5

100 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	23.8	35.3	51.0	70.6	96.0	136.2
2	20.4	32.0	48.[illegible]	67.9	93.2	133.8
4	14.5	26.4	43.4	63.3	88.7	129.9
8	5.3	17.1	35.4	55.8	81.6	123.7
16	0	6.3	24.4	45.5	72.0	115.8

MEAN DIRECTION AND SPEED 284/5.6

200 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	14.7	26.8	39.9	56.1	78.3	112.7
2	12.9	25.2	38.8	55.0	77.3	112.0
4	9.5	22.1	36.6	52.8	75.3	110.4
8	3.9	16.0	32.0	48.4	71.4	107.1
16	0	6.2	22.9	39.6	63.3	100.5

MEAN DIRECTION AND SPEED 293/6.1

Table C1 (contd)

$\sigma^2(\theta)_{T,s}$
(degrees)

SAND STORM NO. 17
DATE 11 July 1963
TIME 0933 PST

12 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	32.9	51.4	87.6	129.5	153.1	153.9
2	28.9	47.7	84.0	126.6	150.8	151.0
4	21.4	40.8	77.4	121.3	146.5	145.9
8	8.4	27.8	64.5	111.0	138.0	136.1
16	0	9.5	44.0	94.2	124.9	121.0

MEAN DIRECTION AND SPEED 267/5.4

50 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	22.8	35.9	62.7	84.0	89.8	103.2
2	18.9	32.0	59.0	80.9	86.9	99.7
4	12.5	25.5	52.8	75.6	82.0	93.8
8	4.3	16.4	43.8	68.5	75.9	85.6
16	0	6.3	31.4	58.8	67.9	74.2

100 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	23.7	38.8	62.3	79.8	87.0	96.9
2	20.7	36.2	59.9	77.9	85.3	94.8
4	14.8	30.9	55.1	74.0	81.7	90.4
8	3.9	21.9	46.7	66.8	74.8	82.7
16	0	8.0	32.0	54.5	63.0	69.5

MEAN DIRECTION AND SPEED 278/6.6

200 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1						
2						
4			MISSING			
8						
16						

MEAN DIRECTION AND SPEED

Table C1 (contd)

$\sigma^2(\theta)_{T,s}$
(degrees)

SAND STORM NO. 18
DATE 15 Jul 1963
TIME 1030 PST

12 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	27.9	40.1	53.7	68.5	100.8	145.4
2	24.1	36.7	50.7	65.5	97.8	142.8
4	17.2	30.7	45.3	60.1	92.4	138.3
8	6.6	29.8	36.6	51.5	83.4	131.3
16	0	6.8	23.2	38.6	69.7	121.1

MEAN DIRECTION AND SPEED 262/8.7

50 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	21.5	29.5	40.2	55.7	84.0	126.1
2	17.6	26.0	36.8	52.2	80.7	123.1
4	11.9	20.9	31.9	47.3	75.8	118.9
8	4.2	13.5	24.9	40.3	68.8	113.2
16	0	4.5	15.7	31.2	59.3	106.4

100 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	13.3	19.9	27.7	40.4	72.3	112.8
2	11.5	18.4	26.3	39.1	71.0	111.8
4	8.3	15.7	22.9	36.8	68.7	110.1
8	3.3	11.1	19.8	32.8	64.8	107.5
16	0	3.9	12.7	25.9	57.5	103.1

MEAN DIRECTION AND SPEED 275/10.0

200 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1						
2						
4		M I S S I N G				
8						
16						

MEAN DIRECTION AND SPEED

Table C1 (contd)

$\sigma^2(\theta)_{T,s}$
(degrees)

SAND STORM NO. 13
DATE 17 July 1963
TIME 0936 PST

12 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	15.9	23.7	29.7	35.3	39.1	37.9
2	13.6	21.7	28.0	33.6	37.5	36.3
4	9.5	18.1	24.8	30.5	34.4	33.3
8	3.6	12.3	20.0	25.9	29.8	28.9
16	0	4.3	12.9	19.2	23.5	22.6

MEAN DIRECTION AND SPEED 251/12.6

50 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	13.7	20.4	27.1	35.5	40.2	39.0
2	11.7	18.6	25.5	33.9	38.6	37.5
4	8.2	15.3	22.7	31.1	35.9	34.9
8	3.1	10.2	18.3	26.9	32.0	31.1
16	0	[illegible].6	12.4	21.4	27.2	26.2

100 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	8.8	14.8	22.2	32.9	38.7	37.3
2	7.7	13.8	21.4	32.2	38.0	36.6
4	5.6	11.8	19.8	30.7	36.9	35.5
8	2.3	8.5	17.1	28.2	34.8	33.5
16	0	3.2	12.1	23.6	30.9	30.0

MEAN DIRECTION AND SPEED 258/14.6

200 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	8.2	12.4	17.0	22.6	24.5	25.3
2	7.1	11.5	16.3	22.0	24.0	24.7
4	5.2	9.9	14.9	20.8	23.0	23.6
8	2.0	6.9	12.5	18.8	21.3	21.8
16	0	2.5	8.5	15.4	18.3	18.9

MEAN DIRECTION AND SPEED 253/16.1

Table C1 (contd)

$\sigma^2(\theta)_{T,s}$
(degrees)

SAND STORM NO. 20
DATE 26 July 1963
TIME 1018 PST

12 Feet

T (sec)

s (sec)	16	32	64	128	256	512
1	42.6	65.5	113.0	194.0	315.9	389.2
2	36.0	59.2	106.7	188.0	309.8	383.5
4	25.9	49.7	97.1	179.0	300.3	375.1
8	10.3	34.0	80.7	163.4	283.6	361.0
16	0	11.8	54.1	137.8	255.9	338.5

MEAN DIRECTION AND SPEED 280/3.9

50 Feet

T (sec)

s (sec)	16	32	64	128	256	512
1	47.8	65.9	94.9	137.4	223.7	314.8
2	40.8	59.6	88.8	131.4	218.6	309.7
4	29.2	49.3	76.8	121.6	210.3	301.6
8	10.7	31.8	61.5	104.5	196.0	287.9
16	0	10.1	38.1	79.9	174.6	269.8

100 Feet

T (sec)

s (sec)	16	32	64	128	256	512
1						
2						
4						
8			M I S S I N G			
16						

MEAN DIRECTION AND SPEED

200 Feet

T (sec)

s (sec)	16	32	64	128	256	512
1	23.9	36.8	50.0	84.6	98.4	99.0
2	20.2	33.3	46.9	61.5	95.2	96.2
4	14.1	27.6	41.7	56.3	89.8	91.7
8	5.0	18.1	33.4	47.9	81.1	84.6
16	0	6.7	22.7	37.9	70.8	75.3

MEAN DIRECTION AND SPEED 270/3.8

Table C1 (contd)

$\sigma^2(\theta)_{T,s}$
(degrees)

SAND STORM NO. 21
DATE 30 July 1963
TIME 1130 PST

12 Feet

T (sec)

s (sec)	16	32	64	128	256	512
1	20.7	29.3	36.0	41.5	50.5	78.1
2	17.7	26.8	33.8	39.5	48.5	76.0
4	12.6	22.3	30.0	35.8	45.0	72.4
8	4.7	14.9	23.5	29.6	38.9	66.5
16	0	4.9	14.5	21.2	30.6	58.5

MEAN DIRECTION AND SPEED 262/7.6

50 Feet

T (sec)

s (sec)	16	32	64	128	256	512
1	18.1	25.3	37.2	52.7	67.7	82.7
2	15.3	22.6	34.6	50.4	65.5	80.5
4	10.6	18.2	30.6	46.9	62.3	77.3
8	3.9	11.6	24.3	41.6	57.5	72.6
16	0	3.8	16.0	34.5	51.3	66.9

100 Feet

T (sec)

s (sec)	16	32	64	126	256	512
1	17.8	29.1	48.2	71.2	90.4	96.6
2	15.4	26.8	46.0	69.4	88.7	95.1
4	11.1	22.8	42.3	66.6	86.1	92.6
8	4.4	16.0	35.3	61.5	81.5	88.5
16	0	5.8	24.5	52.6	73.6	81.9

MEAN DIRECTION AND SPEED 264/9.4

200 Feet

T (sec)

s (sec)	16	32	64	128	256	512
1	18.1	28.3	43.7	59.7	71.2	78.0
2	15.4	26.0	41.4	58.0	69.5	76.6
4	11.0	21.9	37.6	55.0	66.7	73.9
8	4.3	15.3	31.2	50.0	61.9	69.6
16	0	5.4	20.6	41.6	54.2	62.7

MEAN DIRECTION AND SPEED 254/9.0

Table C1 (contd)

$\sigma^2(\theta)_{T,s}$
(degrees)

SAND STORM NO. 22
DATE 9 August 1963
TIME 1458 PST

12 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	40.8	62.4	93.9	147.8	198.5	308.3
2	34.5	56.6	88.9	142.9	194.1	304.3
4	23.7	46.8	80.2	134.6	186.8	297.8
8	9.2	31.9	66.9	121.7	175.8	288.0
16	0	11.7	46.0	101.2	158.6	272.8

MEAN DIRECTION AND SPEED 260/4.3

50 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	39.5	62.9	100.2	159.6	224.5	305.8
2	34.5	58.3	95.9	155.2	220.4	302.1
4	25.1	49.5	87.4	146.6	212.1	294.6
8	9.8	33.8	71.0	131.0	197.4	280.8
16	0	11.8	47.7	106.9	175.1	258.9

100 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	33.3	54.6	90.1	153.6	227.9	297.0
2	29.6	51.4	87.0	150.7	225.1	294.2
4	22.2	44.9	80.7	144.9	219.6	288.5
8	9.1	31.8	67.6	132.4	208.2	276.4
16	0	11.0	44.5	110.0	188.0	254.0

MEAN DIRECTION AND SPEED 250/5.3

200 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	21.4	35.4	55.2	79.1	113.4	134.6
2	17.7	31.8	51.9	75.8	109.7	131.3
4	12.2	26.3	46.9	70.8	104.4	126.4
8	4.5	17.8	39.3	63.5	96.7	119.1
16	0	6.8	27.9	52.9	85.5	108.3

MEAN DIRECTION AND SPEED 259/5.0

Table C1 (contd)

$\sigma^2(\theta)_{T,s}$
(degrees)

SAND STORM NO. 23
DATE 16 August 1963
TIME 1558 PST

12 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	17.6	29.5	44.1	57.1	72.1	93.5
2	14.9	27.0	42.0	55.2	70.2	91.5
4	10.4	22.7	38.4	51.9	67.0	88.0
8	4.1	15.9	32.7	46.8	62.0	82.5
16	0	6.0	23.1	38.1	53.5	72.9

MEAN DIRECTION AND SPEED 265/7.5

50 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	17.9	24.1	33.8	49.6	54.2	74.2
2	14.8	21.2	31.1	47.2	51.9	71.7
4	9.9	16.8	26.9	43.4	48.5	67.8
8	3.4	10.5	20.9	38.1	43.8	62.4
16	0	3.6	13.9	31.5	38.5	55.9

100 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	13.4	18.6	24.6	32.5	37.4	54.2
2	11.4	16.9	23.1	31.2	36.2	52.9
4	7.8	13.6	20.4	29.0	34.1	50.5
8	2.8	8.8	16.4	25.5	30.9	46.9
16	0	3.0	11.0	20.8	26.6	42.1

MEAN DIRECTION AND SPEED 243/9.5

200 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	9.6	15.9	21.0	26.5	29.4	43.9
2	8.3	14.8	20.1	25.7	28.7	43.1
4	6.0	12.7	18.3	24.3	27.5	41.7
8	2.4	9.0	15.2	22.0	25.6	39.2
16	0	3.3	10.3	18.1	22.5	35.2

MEAN DIRECTION AND SPEED 252/9.3

Table C1 (contd)

$\sigma^2(\theta)_{T,s}$
(degrees)

SAND STORM NO. 24
DATE 19 August 1963
TIME 1542 PST

12 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	53.2	73.3	84.4	103.2	102.2	132.7
2	45.1	66.4	78.7	98.4	98.0	127.4
4	31.9	55.1	69.4	90.3	90.7	118.5
8	11.7	36.2	54.2	76.8	78.3	104.2
16	0	12.1	33.9	58.8	62.4	85.5

MEAN DIRECTION AND SPEED 271/5.8

50 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	50.3	62.9	78.1	95.5	86.9	121.4
2	42.3	56.6	72.5	91.2	83.4	116.4
4	29.2	46.4	63.5	84.2	77.6	108.3
8	10.6	30.8	50.3	73.4	68.3	96.3
16	0	10.2	32.0	57.9	54.7	79.3

100 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	40.6	55.9	71.9	86.0	81.4	123.9
2	34.9	51.6	68.3	83.1	79.0	120.8
4	24.4	43.9	62.0	78.3	75.0	115.4
8	9.1	30.8	51.5	70.3	68.7	106.6
16	0	11.0	34.4	57.5	58.7	92.5

MEAN DIRECTION AND SPEED 257/6.8

200 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	30.3	42.5	54.7	75.2	78.8	111.0
2	26.0	39.0	51.6	72.5	76.4	108.3
4	18.6	33.1	46.5	68.3	72.9	104.1
8	6.9	22.6	37.8	60.9	67.3	96.7
16	0	7.9	24.4	49.0	58.9	85.0

MEAN DIRECTION AND SPEED 261/6.4

Table C1 (contd)

$\sigma^2(\theta)_{T,s}$
(degrees)

SAND STORM NO. 25
DATE 21 August 1963
TIME 1334 PST

12 Feet

T (sec)

s (sec)	16	32	64	128	256	512
1	28.2	41.6	62.0	91.2	99.3	138.8
2	24.3	38.0	58.5	88.0	96.3	135.9
4	17.0	31.1	52.0	82.0	90.5	130.5
8	6.1	20.3	41.5	72.3	81.1	122.1
16	0	7.0	27.3	59.0	69.3	111.6

MEAN DIRECTION AND SPEED 263/7.8

50 Feet

T (sec)

s (sec)	16	32	64	128	256	512
1	16.8	24.8	37.4	59.1	68.0	85.9
2	14.2	22.4	35.2	56.9	66.0	84.1
4	9.8	19.4	31.2	53.2	62.4	80.9
8	3.7	12.3	25.2	47.4	57.2	76.2
16	0	4.2	16.7	39.3	50.3	70.2

100 Feet

T (sec)

s (sec)	16	32	64	128	256	512
1						
2						
4		MISSING				
8						
16						

MEAN DIRECTION AND SPEED

200 Feet

T (sec)

s (sec)	16	32	64	128	256	512
1						
2						
4			MISSING			
8						
16						

MEAN DIRECTION AND SPEED

Table C1 (contd)

$\sigma^2(\theta)_{T,s}$
(degrees)

SAND STORM NO. 26
DATE 22 August 1963
TIME 1430 PST

12 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	25.4	40.2	64.3	94.2	135.6	165.9
2	21.8	36.8	61.2	91.3	132.9	163.4
4	15.4	30.6	55.3	86.1	126.0	159.0
8	5.7	20.4	45.5	77.3	119.6	151.7
16	0	7.6	31.3	64.9	107.9	142.5

MEAN DIRECTION AND SPEED 256/9.7

50 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	21.1	34.4	58.9	88.2	125.9	139.4
2	17.9	31.3	56.0	85.7	123.5	137.3
4	12.6	26.1	51.1	81.7	119.7	134.1
8	4.8	17.7	43.1	75.4	113.9	129.3
16	0	6.7	30.5	65.4	104.8	122.7

100 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	15.4	25.0	42.1	63.3	96.0	116.1
2	13.5	23.2	40.5	61.8	94.7	114.9
4	9.6	19.6	37.1	58.8	92.1	112.7
8	3.8	13.3	31.0	53.4	87.4	108.6
16	0	4.7	21.2	44.7	80.1	102.4

MEAN DIRECTION AND SPEED 255/11.4

200 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	14.7	26.0	43.6	62.1	90.9	113.4
2	12.7	24.0	41.9	60.5	89.5	112.1
4	9.2	20.7	38.8	57.8	87.3	110.1
8	3.8	14.7	33.2	52.8	83.1	106.3
16	0	5.4	23.1	43.7	75.6	99.3

MEAN DIRECTION AND SPEED 247/11.0

Table C1 (contd)

$\sigma^2(\theta)_{T,s}$
(degrees)

SAND STORM NO. 27
DATE 27 August 1963
TIME 1538 PST

12 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	30.5	54.3	93.4	122.0	146.4	150.3
2	25.9	49.8	89.4	118.5	142.3	147.2
4	18.7	42.7	83.1	113.4	136.9	142.8
8	7.4	29.9	71.3	104.1	127.5	134.7
16	0	11.4	50.7	88.8	112.7	121.4

MEAN DIRECTION AND SPEED 249/6.4

50 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	34.3	55.3	93.3	139.1	214.9	205.3
2	28.9	50.2	88.4	134.5	209.5	201.5
4	19.9	41.7	80.1	126.7	200.8	195.2
8	7.7	28.8	67.2	115.2	188.3	186.3
16	0	10.4	45.9	96.4	168.1	172.2

100 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	41.1	63.9	96.7	161.3	304.1	286.7
2	34.4	57.9	90.7	154.7	296.6	281.6
4	23.7	48.3	81.3	144.5	285.1	274.0
8	9.5	34.1	67.7	129.8	268.8	263.9
16	0	12.3	44.6	104.3	240.9	247.2

MEAN DIRECTION AND SPEED 249/6.9

200 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	31.1	43.8	64.6	111.6	216.9	219.9
2	27.3	40.6	61.3	108.1	213.0	217.2
4	19.6	34.2	54.4	100.8	205.0	211.8
8	7.5	23.2	42.8	88.3	191.2	202.7
16	0	7.3	25.4	69.0	169.5	189.5

MEAN DIRECTION AND SPEED 239/6.8

Table C1 (contd)

$\sigma^2(\theta)_{T,s}$
(degrees)

SAND STORM NO. 28
DATE 30 August 1963
TIME 1439 PST

12 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	19.4	34.0	54.9	83.2	100.0	123.5
2	16.7	31.4	52.7	81.2	98.1	121.8
4	11.9	26.8	48.8	77.6	94.7	118.9
8	4.7	18.9	41.9	71.2	88.6	113.8
16	0	7.2	29.6	59.3	77.0	104.5

MEAN DIRECTION AND SPEED 255/8.5

50 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	16.8	26.3	42.7	59.2	80.5	106.1
2	14.2	23.8	40.4	67.1	78.5	104.3
4	9.8	19.8	36.4	63.3	75.1	101.2
8	3.8	13.6	30.3	57.5	69.8	96.5
16	0	4.8	20.5	47.8	61.6	89.1

100 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	11.0	18.7	30.7	48.4	60.5	72.2
2	9.6	17.5	29.6	47.5	59.7	71.5
4	6.9	15.2	27.4	45.6	58.0	70.0
8	2.9	11.1	23.5	42.1	55.0	67.4
16	0	4.0	15.7	35.0	49.1	62.0

MEAN DIRECTION AND SPEED 262/8.3

200 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	10.4	16.2	23.0	31.7	40.7	49.0
2	9.0	14.9	21.9	30.5	39.7	47.1
4	6.5	12.6	19.8	28.6	37.8	45.4
8	2.5	8.7	16.3	25.1	34.5	42.6
16	0	3.0	10.6	19.6	29.5	38.3

MEAN DIRECTION AND SPEED 250/8.3

Table C1 (contd)

$\sigma^2(\theta)_{T,s}$
(degrees)

SAND STORM NO. 29
DATE 10 September 1963
TIME 1611 PST

12 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	27.5	41.5	54.1	80.2	79.7	106.5
2	24.2	38.5	61.2	77.7	77.5	103.9
4	17.5	32.6	55.4	72.8	73.0	98.9
8	6.6	21.9	45.0	64.0	65.1	89.8
16	0	7.6	29.5	51.4	54.2	76.8

MEAN DIRECTION AND SPEED 261/7.7

50 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	26.2	39.3	61.0	73.1	73.6	95.4
2	22.6	36.0	57.9	70.5	71.3	92.7
4	16.1	30.1	52.3	66.0	67.4	88.0
8	6.1	20.2	42.7	58.5	61.1	80.3
16	0	6.9	28.2	47.2	52.1	69.1

100 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	19.1	30.1	47.2	56.1	59.2	74.2
2	16.8	28.2	45.5	54.6	57.9	72.7
4	12.4	24.5	42.1	51.8	55.4	70.0
8	5.1	17.5	35.6	46.9	51.3	65.1
16	0	6.1	24.0	38.5	44.8	56.8

MEAN DIRECTION AND SPEED 265/9.5

200 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	13.6	24.7	42.4	51.6	64.2	72.8
2	11.9	23.1	41.1	50.4	63.1	71.7
4	8.8	20.0	38.4	48.0	61.0	69.6
8	3.5	14.1	33.1	43.5	57.2	65.3
16	0	5.4	23.6	35.7	50.4	58.1

MEAN DIRECTION AND SPEED 250/10.5

Table C1 (contd)

$\sigma^2(\theta)_{T,s}$
(degrees)

SAND STORM NO. 30
DATE 11 September 1963
TIME 1526 PST

12 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	60.2	97.2	139.2	200.1	301.0	654.2
2	49.5	87.1	129.7	191.1	293.1	644.7
4	34.1	72.5	116.1	178.2	281.6	630.7
8	13.2	50.1	95.6	158.7	263.7	603.7
16	0	19.0	64.1	128.7	236.4	572.1

MEAN DIRECTION AND SPEED 261/2.9

50 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	50.0	73.3	104.2	170.6	304.1	511.4
2	41.6	65.8	96.9	163.5	297.9	504.9
4	28.9	54.5	85.9	152.8	288.6	495.4
8	10.8	36.6	68.6	135.7	274.2	480.6
16	0	13.2	44.5	111.3	253.7	459.8

100 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	28.4	37.8	52.5	94.9	211.8	381.4
2	23.5	33.6	48.4	90.8	208.0	377.8
4	16.8	27.8	42.7	85.0	202.4	373.2
8	6.2	18.1	33.1	75.0	192.9	365.5
16	0	5.8	20.6	60.9	179.3	355.5

MEAN DIRECTION AND SPEED 266/3.6

200 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	35.8	53.1	76.3	108.1	190.6	341.9
2	31.1	49.0	72.4	104.3	186.8	338.7
4	22.5	41.4	65.3	97.4	179.8	332.8
8	8.4	27.7	52.5	85.0	167.4	322.3
16	0	9.7	34.2	67.6	149.2	308.3

MEAN DIRECTION AND SPEED 244/3.4

$\sigma^2(\theta)_{T,s}$
(degrees)

SAND STORM NO. 31
DATE 12 Sep 1963
TIME 1501 PST

12 Feet

T (sec)

s (sec)	16	32	64	128	256	512
1	13.0	16.2	19.8	24.7	33.6	36.7
2	10.6	14.0	17.8	22.7	31.6	34.8
4	6.7	10.4	14.4	19.5	28.4	31.8
8	2.2	6.1	10.4	15.6	24.8	28.2
16	0	1.9	6.2	11.6	21.1	24.8

MEAN DIRECTION AND SPEED 266/8.9

50 Feet

T (sec)

s (sec)	16	32	64	128	255	512
1	8.4	10.7	14.0	19.8	32.3	38.1
2	6.9	9.4	12.7	18.5	31.1	37.0
4	4.7	7.3	10.7	16.6	29.4	35.3
8	1.6	4.4	7.9	14.0	27.0	33.1
16	0	1.3	4.8	10.8	24.1	30.9

100 Feet

T (sec)

s (sec)	16	32	64	128	256	512
1	4.5	6.7	9.8	16.3	34.3	44.9
2	3.8	6.1	9.2	15.7	33.7	44.5
4	2.6	5.0	8.1	14.6	32.6	43.7
8	0.9	3.3	6.5	12.5	31.0	42.7
16	0	1.1	4.2	10.3	28.2	41.3

MEAN DIRECTION AND SPEED 279/11.2

200 Feet

T (sec)

s (sec)	16	32	64	128	256	512
1	2.9	4.6	6.5	10.3	21.7	29.3
2	2.5	4.2	6.2	10.0	21.3	29.0
4	1.7	3.4	5.5	9.2	20.7	28.6
8	0.6	2.3	4.6	8.3	19.6	27.9
16	0	0.8	3.1	6.7	17.8	27.0

MEAN DIRECTION AND SPEED 257/10.6

Table C1 (contd)

$\sigma^2(\theta)_{T,s}$
(degrees)

SAND STORM NO. 32
DATE 16 Sep 1963
TIME 1413 PST

12 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	16.5	24.9	40.2	72.8	97.0	145.3
2	14.1	22.6	37.9	70.6	95.0	143.6
4	9.9	18.6	33.9	66.6	91.5	140.8
8	3.6	12.1	27.5	60.2	86.0	136.5
16	0	4.4	18.7	50.8	78.6	131.4

MEAN DIRECTION AND SPEED 264/8.8

50 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	12.1	17.7	25.3	39.8	60.1	115.5
2	10.2	15.9	23.5	38.0	58.4	113.8
4	6.7	12.6	20.3	34.0	55.4	110.9
8	2.3	8.1	16.0	30.4	51.1	107.3
16	0	2.9	10.6	24.8	45.7	102.9

100 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	11.6	18.1	25.5	40.6	59.3	95.5
2	10.2	16.9	24.4	39.4	58.2	94.5
4	7.5	14.5	22.3	37.2	56.0	92.7
8	2.9	10.1	18.2	32.9	51.6	89.2
16	0	3.5	11.8	25.9	44.4	83.4

MEAN DIRECTION AND SPEED 266/9.6

200 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	11.2	17.4	23.8	33.8	43.7	63.5
2	9.7	16.2	22.7	32.7	42.6	62.5
4	6.9	13.9	20.6	30.6	40.6	60.6
8	2.7	9.8	16.9	26.8	37.0	57.3
16	0	3.5	10.9	20.7	31.3	51.7

MEAN DIRECTION AND SPEED 258/10.4

Table C1 (contd)

$\sigma^2(\theta)_{T,s}$
(degrees)

SAND STORM NO. 33
DATE 8 Oct 1963
TIME 1543 PST

12 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	22.0	25.8	27.9	31.1	34.7	40.0
2	18.9	23.2	25.4	28.5	32.1	37.4
4	13.3	18.3	20.7	23.8	27.4	32.9
8	4.6	10.7	13.6	16.7	20.2	25.0
16	0	2.8	6.5	9.8	13.5	18.8

MEAN DIRECTION AND SPEED 258/4.5

50 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	14.0	17.2	21.2	26.9	33.8	41.6
2	12.0	15.4	19.5	25.2	32.1	39.9
4	8.3	12.3	16.5	22.2	29.0	37.1
8	3.0	7.6	11.9	17.7	24.5	32.9
16	0	2.1	6.3	12.2	19.1	27.9

100 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	7.5	11.4	14.4	17.0	20.4	23.5
2	6.4	10.6	13.7	16.2	19.6	22.7
4	4.6	9.1	12.4	14.9	18.3	21.4
8	1.8	6.4	10.1	12.9	16.3	19.3
16	0	2.2	6.4	9.6	12.9	15.8

MEAN DIRECTION AND SPEED 249/5.2

200 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	5.7	9.1	11.8	14.6	20.5	27.5
2	5.0	8.5	11.3	14.2	20.0	27.0
4	3.7	7.4	10.5	13.3	19.2	26.2
8	1.5	5.2	8.8	11.7	17.4	24.4
16	0	1.8	5.9	8.8	14.2	21.4

MEAN DIRECTION AND SPEED 252/6.0

Table C1 (contd)

$\sigma^2(\theta)_{T,s}$
(degrees)

SAND STORM NO. 34
DATE 9 Oct 1963
TIME 1408 PST

12 Feet

T (sec)

s (sec)	16	32	64	128	256	512
1	32.3	53.4	88.5	131.1	137.2	156.2
2	27.7	49.2	84.5	127.6	134.3	153.2
4	19.7	41.7	77.5	121.4	129.4	148.0
8	8.0	29.4	65.7	110.8	121.6	139.6
16	0	10.7	45.1	92.2	109.1	125.6

MEAN DIRECTION AND SPEED 263/6.6

50 Feet

T (sec)

s (sec)	16	32	64	128	256	512
1	37.4	68.8	112.1	168.8	198.5	216.1
2	32.2	64.0	107.7	164.9	195.0	212.9
4	23.3	55.5	100.2	158.3	189.2	207.6
8	9.7	40.2	86.4	146.3	178.9	198.0
16	0	15.5	60.9	122.9	159.0	179.8

100 Feet

T (sec)

s (sec)	16	32	64	128	256	512
1	15.8	27.3	50.0	80.0	90.9	101.5
2	13.3	24.9	47.7	78.0	89.1	99.8
4	9.3	20.8	43.6	74.8	86.0	96.9
8	3.5	14.2	36.9	69.5	81.3	92.4
16	0	5.5	26.0	60.5	73.6	85.1

MEAN DIRECTION AND SPEED 253/6.8

200 Feet

T (sec)

s (sec)	16	32	64	128	256	512
1	19.2	30.6	47.8	72.5	80.9	85.9
2	16.7	28.4	45.6	70.5	78.8	84.2
4	12.1	24.3	41.5	66.8	75.0	80.9
8	4.7	16.9	34.2	60.3	68.6	75.3
16	0	6.0	22.3	49.8	59.4	66.5

MEAN DIRECTION AND SPEED 244/8.1

Table C1 (contd)

$\sigma^2(\theta)_{T,s}$
(degrees)

SAND STORM NO. 35
DATE 11 Oct 1963
TIME 1447 PST

12 Feet

T (sec)

s (sec)	16	32	64	128	256	512
1	14.2	18.1	20.8	24.1	24.1	24.8
2	11.9	16.1	18.9	22.2	22.2	23.0
4	8.0	12.7	15.7	19.1	19.2	20.1
8	2.8	7.9	11.4	14.9	15.0	16.1
16	0	2.5	6.5	10.1	10.5	11.8

MEAN DIRECTION AND SPEED 292/10.8

50 Feet

T (sec)

s (sec)	16	32	64	128	256	512
1						
2						
4			MISSING			
8						
16						

100 Feet

T (sec)

s (sec)	16	32	64	128	256	512
1	5.5	6.8	9.3	11.4	9.7	12.2
2	4.7	6.1	8.6	10.8	9.1	11.7
4	3.3	4.9	7.4	9.7	8.1	10.6
8	1.2	2.9	5.5	7.9	6.6	9.0
16	0	0.8	3.3	6.0	5.0	7.2

MEAN DIRECTION AND SPEED 289/12.7

200 Feet

T (sec)

s (sec)	16	32	64	128	256	512
1	2.3	3.4	4.9	6.6	5.9	8.8
2	1.9	3.0	4.5	6.3	5.6	8.5
4	1.2	2.4	4.0	5.8	5.2	8.1
8	0.4	1.6	3.2	5.2	4.7	7.5
16	0	0.5	2.2	4.3	4.0	6.8

MEAN DIRECTION AND SPEED 279/13.7

Table C1 (contd)

$\sigma^2(\theta)_{T,s}$
(degrees)

SAND STORM NO. 36
DATE 15 Oct 1963
TIME 1608 PST

12 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	14.4	17.8	23.7	34.9	43.2	58.8
2	12.1	15.7	21.7	32.9	41.2	56.9
4	8.2	12.3	18.2	29.6	38.0	53.7
8	2.8	7.4	13.3	24.6	33.4	49.0
16	0	2.1	7.5	18.6	28.0	43.3

MEAN DIRECTION AND SPEED 252/6.6

50 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	11.6	14.2	19.6	32.3	41.0	64.0
2	9.6	12.3	17.7	30.4	39.3	62.1
4	6.2	9.1	14.4	27.0	36.1	58.8
8	1.9	5.0	10.2	22.7	32.3	54.5
16	0	1.5	6.1	18.2	28.9	49.9

100 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	5.2	6.9	10.6	21.2	30.2	60.5
2	4.6	6.3	10.1	20.6	29.7	59.9
4	3.3	5.2	8.9	19.5	28.9	58.6
8	1.2	3.3	7.0	17.6	27.4	56.4
16	0	0.9	4.4	14.7	25.3	52.8

MEAN DIRECTION AND SPEED 274/7.2

200 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	4.1	6.1	10.1	19.2	22.6	39.5
2	3.5	5.6	9.6	18.7	22.3	38.9
4	2.5	4.7	8.6	17.8	21.6	37.9
8	0.9	3.1	7.0	16.3	20.4	36.1
16	0	1.1	4.7	13.8	18.7	33.0

MEAN DIRECTION AND SPEED 262/7.5

Table C1 (contd)

$\sigma^2(\theta)_{T,s}$
(degrees)

SAND STORM NO. 37
DATE 22 Oct 1963
TIME 1534 PST

12 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	16.8	24.1	35.6	43.1	48.6	67.7
2	14.3	21.8	33.5	41.2	46.6	65.7
4	10.0	17.9	29.8	37.9	43.1	62.3
8	3.7	11.8	23.8	32.6	37.4	57.0
16	0	3.8	15.3	25.3	29.2	49.5

MEAN DIRECTION AND SPEED 235/6.4

50 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	12.9	18.1	25.5	29.4	36.9	62.0
2	10.8	16.2	23.8	27.8	35.3	60.5
4	7.3	13.0	20.9	25.1	32.5	57.9
8	2.7	8.5	16.8	21.4	28.7	54.4
16	0	2.9	11.0	16.5	23.6	49.6

100 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	10.2	15.3	18.0	18.4	21.1	44.4
2	8.8	14.1	17.1	17.6	20.4	43.5
4	6.3	11.8	15.3	16.2	19.0	41.8
8	2.3	7.8	12.3	13.9	16.9	39.0
16	0	2.7	7.9	10.8	14.0	35.1

MEAN DIRECTION AND SPEED 257/6.8

200 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	9.3	15.6	22.3	25.6	25.6	51.7
2	8.0	14.4	21.3	24.8	24.8	50.7
4	5.7	12.2	19.4	23.2	23.4	48.8
8	2.2	8.5	16.2	20.7	21.0	45.4
16	0	3.1	11.0	16.8	17.3	39.8

MEAN DIRECTION AND SPEED 245/7.1

Table C1 (contd)

$\sigma^2(\theta)_{T,s}$
(degrees)

SAND STORM NO. 38
DATE 23 Oct 1963
TIME 1335 PST

12 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	19.4	26.0	35.1	46.2	51.3	56.6
2	16.5	23.4	32.6	43.9	49.2	54.4
4	11.5	19.0	28.3	40.0	45.6	50.6
8	4.2	12.3	22.0	34.3	40.6	45.0
16	0	4.0	13.5	26.6	33.6	37.4

MEAN DIRECTION AND SPEED 246/9.3

50 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	12.0	16.6	24.7	36.1	42.7	45.9
2	10.0	14.8	23.0	34.4	41.2	44.4
4	6.6	11.7	19.9	31.5	38.7	41.7
8	2.3	7.4	15.6	27.6	35.3	38.0
16	0	2.5	10.3	22.8	31.2	33.7

100 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	6.0	9.1	15.1	22.7	27.0	31.3
2	5.1	8.2	14.2	22.0	26.3	30.5
4	3.5	6.7	12.7	20.6	25.0	29.3
8	1.3	4.3	10.3	18.4	22.8	27.3
16	0	1.5	7.0	15.6	20.2	24.7

MEAN DIRECTION AND SPEED 265/11.0

200 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	5.4	8.8	13.2	17.9	19.2	22.6
2	4.6	8.0	12.5	17.3	18.7	22.0
4	3.2	6.8	11.4	16.3	17.7	21.0
8	1.2	4.7	9.5	14.6	16.2	19.4
16	0	1.7	6.5	12.1	14.0	17.0

MEAN DIRECTION AND SPEED 256/11.1

Table C1 (contd)

$\sigma^2(\theta)_{T,s}$
(degrees)

SAND STORM NO. 39
DATE 29 Oct 1963
TIME 1445 PST

12 Feet

T (sec)

s (sec)	16	32	64	128	256	512
1	39.1	58.9	86.2	112.4	152.2	323.4
2	33.5	53.9	82.0	108.7	149.0	319.4
4	23.8	45.4	74.8	102.4	143.4	312.6
8	9.4	31.6	62.8	92.2	134.3	301.5
16	0	11.5	43.2	76.2	120.4	284.0

MEAN DIPECTION AND SPLED 228/3.5

50 Feet

T (sec)

s (sec)	16	32	64	128	256	512
1	37.8	65.1	95.6	118.0	167.7	356.5
2	31.6	59.6	91.5	114.5	164.6	352.9
4	22.6	51.1	85.1	109.1	159.5	347.3
8	9.0	36.1	73.5	99.5	150.4	337.5
16	0	13.8	52.5	82.[illegible]	134.9	320.5

100 Feet

T (sec)

s (sec)	16	32	64	128	256	512
1	37.2	60.2	71.9	92.2	164.5	349.0
2	31.0	55.0	68.1	88.8	161.2	345.7
4	21.5	46.8	62.0	83.1	155.6	340.3
8	8.8	33.3	51.6	73.0	145.5	331.0
16	0	12.2	34.0	56.6	129.0	315.9

MEAN DIRECTION AND SPEED 236/4.1

200 Feet

T (sec)

s (sec)	16	32	64	128	256	512
1	45.8	83.2	81.9	71.1	70.0	131.4
2	40.4	79.0	78.8	68.5	67.6	128.4
4	30.4	70.4	73.0	63.8	63.3	122.6
8	12.9	51.8	61.2	54.6	55.2	111.3
16	0	19.6	39.8	38.7	42.1	91.6

MEAN DIRECTION AND SPEED 227/4.2

Table C1 (contd)

$\sigma^2(\theta)_{T,s}$
(degrees)

SAND STORM NO. 40
DATE 30 Oct 1963
TIME 1131 PST

12 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	25.6	35.1	48.8	73.4	103.3	111.6
2	21.7	31.7	45.5	70.5	100.7	108.8
4	15.2	25.9	40.1	65.5	96.4	104.2
8	5.7	17.1	31.4	57.8	89.7	97.0
16	0	5.8	19.7	47.0	80.5	87.5

MEAN DIRECTION AND SPEED 232/6.8

50 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	26.4	34.3	44.5	62.9	88.0	106.2
2	23.1	31.4	41.9	60.5	85.6	103.9
4	16.5	25.9	36.9	55.9	81.3	99.4
8	6.2	17.0	28.6	49.5	74.5	92.0
16	0	5.4	17.2	38.3	65.1	81.9

100 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	15.2	19.9	28.5	43.2	58.2	82.1
2	13.1	18.1	26.8	41.8	56.9	80.7
4	9.3	14.8	23.8	39.2	54.6	78.2
8	3.3	9.3	18.6	34.7	50.5	73.9
16	0	3.1	11.7	28.6	45.5	68.2

MEAN DIRECTION AND SPEED 256/8.1

200 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	13.7	18.6	24.0	35.8	55.0	85.7
2	12.0	17.1	22.6	34.3	53.6	84.3
4	8.6	14.2	19.9	31.7	50.9	81.8
8	3.2	9.3	15.2	27.0	46.2	77.3
16	0	2.8	8.9	20.8	40.4	71.1

MEAN DIRECTION AND SPEED 246/7.1

Table C1 (contd)

$\sigma^2(\theta)_{T,s}$
(degrees)

SAND STORM NO. 41
DATE 4 Nov 1963
TIME 1208 PST

12 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	18.3	25.2	32.8	44.0	56.9	55.7
2	15.0	22.3	30.1	41.4	54.5	53.2
4	9.9	17.5	25.7	37.1	50.4	49.3
8	3.3	10.9	19.8	31.3	45.0	44.2
16	0	3.9	13.0	24.6	38.7	38.9

MEAN DIRECTION AND SPEED 235/9.0

50 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	18.6	24.0	30.0	40.1	48.8	47.1
2	15.5	21.1	27.3	37.5	46.4	44.6
4	10.5	16.5	23.1	33.5	42.6	40.8
8	3.5	9.8	17.4	28.1	37.6	35.8
16	0	3.3	11.4	22.1	32.5	30.8

100 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	9.3	11.9	15.5	20.4	26.4	25.3
2	8.0	10.8	14.5	19.6	25.7	24.5
4	5.7	8.9	12.9	18.1	24.4	23.1
8	2.1	5.8	10.3	15.9	22.5	21.0
16	0	1.8	6.6	12.5	19.[illegible]	18.1

MEAN DIRECTION AND SPEED 259/11.2

200 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	8.3	12.0	16.1	18.3	24.9	26.9
2	7.2	11.0	15.3	17.6	24.3	26.2
4	5.2	9.2	13.9	16.5	23.4	25.0
8	2.0	6.2	11.4	14.5	21.9	23.1
16	0	2.0	7.6	11.5	19.6	20.3

MEAN DIRECTION AND SPEED 252/9.8

Table C1 (contd)

$\sigma^2(\theta)_{T,s}$
(degrees)

SAND STORM NO. 42
DATE 5 Nov 1963
TIME 1425 PST

12 Feet

T (sec)

s (sec)	16	32	64	128	256	512
1	16.3	22.5	29.9	34.9	39.7	40.8
2	13.5	19.8	27.3	32.3	37.3	38.3
4	8.8	15.3	23.1	28.3	33.3	34.2
8	2.9	9.5	17.8	23.2	28.4	29.1
16	0	3.3	11.8	17.8	22.7	23.6

MEAN DIRECTION AND SPEED 228/10.2

50 Feet

T (sec)

s (sec)	16	32	64	128	256	512
1	11.8	14.9	19.1	26.6	34.3	35.7
2	9.9	13.1	17.4	24.8	32.6	34.1
4	6.8	10.0	14.6	22.0	29.8	31.5
8	2.5	6.5	10.8	18.1	25.8	27.8
16	0	1.8	5.1	13.2	21.1	13.4

100 Feet

T (sec)

s (sec)	16	32	64	128	256	512
1	5.5	7.9	11.0	16.5	20.9	22.9
2	4.7	7.2	10.4	15.9	20.3	22.3
4	3.3	6.0	9.2	14.7	19.1	21.3
8	1.3	4.1	7.3	12.8	17.2	19.7
16	0	1.3	4.5	9.8	14.6	17.0

MEAN DIRECTION AND SPEED 251/12.1

200 Feet

T (sec)

s (sec)	16	32	64	128	256	512
1	4.7	6.6	10.1	14.6	18.0	21.5
2	4.1	6.0	9.5	14.2	17.5	21.1
4	3.0	5.1	8.6	13.3	16.7	20.3
8	1.1	3.3	6.9	11.7	15.1	18.9
16	0	1.0	4.3	9.3	13.0	16.8

MEAN DIRECTION AND SPEED 242/12.4

$\sigma^2(\theta)_{T,s}$
(degrees)

SAND STORM NO. 43
DATE 7 Nov 1963
TIME 1[illegible]22 PST

12 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	18.5	27.0	39.8	56.8	66.5	74.0
2	15.6	24.3	37.3	54.4	64.4	71.9
4	10.8	20.0	33.3	50.6	61.0	68.6
8	3.9	13.0	26.8	44.5	55.8	63.5
16	0	4.6	17.9	36.1	49.2	56.9

MEAN DIRECTION AND SPEED 232/7.3

50 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	11.2	17.0	24.8	37.7	48.9	54.8
2	9.4	15.3	23.2	36.2	47.[illegible]	53.4
4	6.4	12.6	20.7	33.7	45.5	51.3
8	2.4	8.6	17.0	30.0	4[illegible].6	48.3
16	0	3.0	11.3	24.2	3[illegible].0	43.7

100 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	8.6	12.6	17.8	27.4	35.8	40.7
2	7.5	11.5	16.8	26.4	35.0	39.9
4	5.2	9.5	14.9	24.5	33.4	38.2
8	1.9	6.3	11.8	21.4	30.7	35.6
16	0	2.1	7.4	16.9	27.0	31.9

MEAN DIRECTION AND SPEED 255/8.5

200 Feet

s (sec)	T (sec) 16	32	64	128	256	512
1	6.4	11.2	16.5	22.9	30.5	3[illegible].8
2	5.4	10.3	15.8	22.2	29.9	34.2
4	3.8	8.7	14.5	21.0	28.8	33.1
8	1.5	6.[illegible]	12.4	19.0	27.1	31.4
16	0	2.3	8.9	15.7	24.4	28.4

MEAN DIRECTION AND SPEED 246/8.4

Table C1 (contd)

$\sigma^2(\theta)_{T,s}$
(degrees)

SAND STORM NO. 44
DATE 13 Nov 1963
TIME 1408 PST

12 Feet

T (sec)

s (sec)	16	32	64	128	256	512
1	33.3	51.6	78.3	120.2	143.7	156.9
2	28.7	47.5	74.5	116.8	140.7	153.9
4	20.7	40.2	67.9	110.6	135.4	148.8
8	8.0	27.5	56.1	99.6	125.9	140.0
16	0	9.7	37.7	81.8	111.0	126.6

MEAN DIRECTION AND SPEED 241/4.5

50 Feet

T (sec)

s (sec)	16	32	64	128	256	512
1	21.9	34.7	55.6	93.4	128.8	149.7
2	18.5	31.5	52.6	90.5	126.1	147.3
4	12.9	26.3	47.5	85.4	121.6	143.5
8	4.9	17.9	39.4	77.2	114.5	137.6
16	0	6.5	26.8	64.5	103.6	129.1

100 Feet

T (sec)

s (sec)	16	32	64	128	256	512
1	15.0	22.9	38.1	59.5	102.5	119.7
2	12.9	20.9	36.1	67.4	100.6	11[illegible].2
4	9.2	17.1	32.4	63.5	97.0	115.4
8	3.2	10.8	26.0	56.7	90.7	110.7
16	0	3.8	17.5	47.7	83.2	105.5

MEAN DIRECTION AND SPEED 266/4.6

200 Feet

T (sec)

s (sec)	16	32	64	128	256	512
1	14.6	21.5	32.7	52.7	76.3	92.0
2	12.7	19.7	30.9	50.9	74.5	90.6
4	9.0	16.2	27.6	47.5	71.2	87.9
8	3.4	10.7	22.1	41.9	66.2	83.7
16	0	3.5	14.3	33.8	59.1	78.1

MEAN DIRECTION AND SPEED 251/4.8

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13. ABSTRACT

A series of field experiments in atmospheric diffusion was conducted at Edwards Air Force Base, California, in 1963. The primary feature which distinguished this series from similar experimental investigations was that instantaneous sources were studied. Puffs of tracer material were generated quasi-instantaneously by short bursts of small, horizontally fired, solid propellant rocket motors. Tracer samples were collected on a horizontal grid that had 350 sampling positions. All of the 43 experiments were conducted under thermally unstable atmospheric conditions.

Analyses of the data identified the region of the turbulent energy spectrum which contains the eddies that are effective in diffusing the clouds. Eulerian measurements of turbulence are shown to be correlated with lateral rates of cloud growth. Downwind distributions of peak inhalation-level dosages were found to be quite irregular, with the anomalies unpredictable on the basis of measurable meteorological parameters. It was, nevertheless, possible to develop an operationally useful estimating equation relating peak dosages to distance from the source.

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